COUNCIL OF SCIENTIFIC AND INDUSTRIAL RESEARCH

THE

NEW ZEALAND JOURNAL OF SCIENCE AND TECHNOLOGY

VOLUME 26

A. AGRICULTURAL SECTION

WELLINGTON, N.Z.
BY AUTHORITY: E. V. PAUL, GOVERNMENT PRINTER
1945

CONTENTS

VOLUME 26, 1944–45

A. AGRICULTURAL SECTION

No. 1.—June, 1944

No. 2.—August, 1944

No. 3.—October, 1944

No. 4.—December, 1944

No. 5.—February, 1945

No. 6.—April, 1945

THE NEW ZEALAND
JOURNAL OF SCIENCE
AND
TECHNOLOGY

Editor: D. Cairns, M.Sc., Department of Scientific and Industrial Research, Wellington

VOL. 26, SEC. A — JUNE, 1944 — NUMBER 1

SIGNIFICANCE OF HAIRINESS TO THE WOOL TEXTILE INDUSTRY

PART I.—ROMNEY HOGGET WOOLS

By S. TOWNEND and P. R. MCMAHON, Department of Scientific and Industrial Research, New Zealand

Summary

In the first of a series of experiments designed to discover the real importance of hairiness (medullated fibre) to the woolgrower, manufacturer, and user, two batches of raw wool have been followed with detailed observations throughout all stages of processing to the finished fabric. In this trial the wool used was obtained from about seven hundred unculled stud Romney ewe hoggets—not shorn as lambs—from a flock not greatly superior to the standard of all Romney stud sheep in the Dominion. The two batches contained:—

A: 198 lb. of wool from the sheep graded highest for freedom from hairiness; and

B: 203 lb. from the sheep graded lowest.

For each batch, britch and hind-quarter wool only were selected after normal skirting, and the mean photo-electric indices were—A, 3·2 cm./g. and B, 7·8 cm./g. The batches were matched so as to be practically identical in mean fibre length (A, 22·9 cm. and B, 21·5 cm.) and fineness (A, 33·6μ and B, 33·3μ), corresponding to the trade specification of super 48/50's preparing hogget wool.

Although the *difference* in hairiness between the two batches was relatively small and equivalent to only 4·6 per cent. of coarse, hairy fibre it was clearly visible in the bulked raw material. This difference did not affect the processing properties of the wool, and produced no marked difference in appearance and handle of either woven or knitted fabrics; it could not be detected in finished cloths dyed navy blue in either an acid or a neutral bath.

The test has demonstrated the unique opportunities available in New Zealand for research work in which the inter-relationships between the problems of the wool-producer and those of the wool-manufacturer can be studied.

INTRODUCTION

IN examining wool, one of the important characteristics which commands the buyers' attention is hairiness. For the majority of purposes it is considered desirable to have wool as free from hair as possible, and many sheepmen cull their flocks season after season in order to get fleeces with progressively less hairy fibre.

19543

Studies of hairiness, or medullation, have always had a prominent place in New Zealand wool-research programmes. The development by Elphick (1932) and later by McMahon (1937) of a rapid and accurate means for assessing the amount of medulla in wool led to the formation by Waters (1935) of an official fleece testing and recording organization at the Massey Agricultural College to assist breeders in grading and culling their flocks. Despite the attention given to hairiness by wool-producers and by certain sections of the Bradford trade (Sidey, 1931), however, there is little factual information on record as to its real significance to the textile industry, especially when the medulla is only present in small quantities, is fine in relation to the diameter of the fibre, or occupies only a small proportion of its length. Lang (1942), in work just published, has reviewed comprehensively what little has been written on the occurrence and the significance of hairy fibres in wool. He points out that "the wool buyer, appraiser, and classer appear to be quite capable of detecting the coarser hair fibres and sometimes of the finer hairs," and that "3 per cent. of coarse hair causes the appraiser to regard a 58's with suspicion." In the case of the stronger types of crossbred wool (40's to 50's), which constitute the major part of New Zealand's clip, on the other hand, rather different results were obtained when samples differing in hairiness were submitted, by courtesy of the New Zealand Department of Agriculture, to a committee of wool-appraisers (Table I). Although the presence of hairy fibres was noted by the appraisers in samples relatively free from medulla, no price discrepancy was made until the amount present had reached a fairly high level. Similar samples, when submitted to competent authorities in wool-manufacturing circles, elicited the general comment that in large quantities the wools represented by the 18–29 groups would not be included in the same grade as the rest, because they were appreciably more hairy. A minority also included the 13–18 group as inferior, but it was usually agreed that in small quantities the 18–29 and even the 29–39 groups could be included for most classes of work. It seems apparent that, while a small amount of hair can have an appreciable effect on fabrics made from finer types of wool, the rougher cloths for which our stronger types of crossbred wool (40's to 50's) are suitable do not suffer from the admixture of relatively large amounts of hair. Handle and style play a larger part in determining the value of finely-spun materials; coarser fabrics are generally required more for service and durability.

TABLE I

Equivalent Percentage of Coarse, Hairy Fibre.	Count.*	Appraiser's Grading.
0–2	50	A
2–4	48/50	A
4–6	48/50	A
6–8	48	A
8–13	48	A
13–18	46/48	A
18–29	46	A
29–39	44/46	BB

* These samples were selected, in the first instance, without reference to count. The results clearly show that it is easier to obtain large amounts of medulla in coarser wools, but the correlation is not sufficiently high to interfere with the selection of both fine wools of high medullation and coarse wools free from the defect.

Opinions such as these, however, cannot be accepted as final without more objective tests of the behaviour of hairy wool during manufacture. The present investigation was undertaken because of the prominence that this characteristic of wool commands both in New Zealand and abroad, especially among sheepmen, and also because of the lack of real information about the level at which the defect becomes serious.

It is intended that the trial should be regarded as a preliminary study for the solution of two questions: Firstly, what influence have hairy fibres on the processes of wool-manufacture and on the finished fabric; and, secondly, are there any differences either in the processing or in the finished fabrics which cannot be accounted for solely by the hairy fibres? That is, are there any differences between the pure wool fibres growing on hairy and non-hairy animals when the fleeces are comparable in length and fineness? The present paper reports the selection and analysis of two lots of wool, A and B, apparently differing only in hairiness; the comparison of the conversion of these two lots of wool into fabrics under conditions as nearly identical as possible; and, finally, the examination of the finished materials for differences of practical or commercial significance.

In addition to findings on these subjects, the writers consider the present investigation to be important in demonstrating the unique opportunities available in New Zealand for the collaboration of research workers in wool-production and wool-manufacture. Thus, while the farmer for his part is anxious to take every opportunity for improving his product, the New Zealand wool-manufacturers are also intimately interested in sheep-farming not only because of closer personal ties between our urban and our rural populations, but because their activity is dependent in large measure upon the prosperity of the sheep-farmer. The facilities, too, for this type of investigation are excellent. On the animal side, greasy wool of known history is readily available for most classes of manufacture or, through our production research organizations, can even be specially grown for the work. On the manufacturing side, one special advantage offered by the industry in this country for such work is its organization in vertical units, especially when, as in the present case, the mill is fitted out with modern plant. In the present trial, two lots of wool were selected from a flock of stud sheep which has been under scientific observation for a number of years, and converted from raw material to finished fabric in one mill under test conditions with relatively little interference with production.

It is important to realize that the results have been achieved without it being necessary for the production research organization to own the sheep or for the textile research institution to possess elaborate industrial plant. In this trial, perhaps for the first time in the history of the wool industry, the close and friendly co-operation of both sheep-farmer and wool-manufacturer has been generously given, and it is to be hoped that these special conditions will be utilized for similar work in the future.

Because of certain abnormal conditions arising out of the war it has been necessary, unfortunately, to terminate this investigation hurriedly. This has meant that some of the finer points which might profitably have been dealt with in the report have had to be omitted. Despite this, it is thought that the recording of the results and notes on this work will prove of interest to some workers on both wool production and manufacturing problems.

RAW GREASY WOOL

Selection

It was clear that the difference in hairiness aimed at in choosing the two lots of raw materials must not be such as to place the wools into different categories of manufacture, while too small a difference could hardly be expected to have effects of commercial significance. The results of submitting samples with varying degrees of hairiness to experienced woolmen suggested that a difference of the order of 15 per cent. of coarse, hairy fibre would not be too great in the stronger types of crossbred wool, but inspection of fleece-testing records accumulated at the Massey Agricultural College soon showed that it would be impossible to accumulate large batches of wool with as large a difference as this if quality were to be maintained and unevenness in fibre diameter and length avoided. The latter requirement

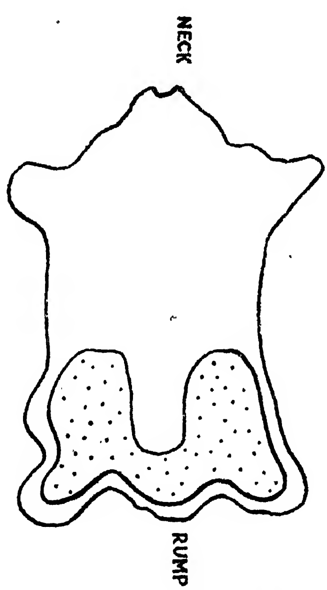


FIG. 1.—Fleece area selected for inclusion in test lots.

made it desirable to use wool from stud sheep, while to secure an appreciable difference in average hairiness between the two batches it became necessary to concentrate on wool from the hind quarters and britch (Fig. 1). In this way it was hoped to procure one line of hind-quarters wool substantially free from hair, and a similar line having medullation equivalent to 8 per cent. to 10 per cent. of coarse, hairy fibre. Hogget wool was chosen as the most suitable raw material for the test, because of its fineness. If wool from the ewe flock were used, the amount of hairy fibre would be less, while the lower quality, in terms both of fineness and variability in character and length, would limit the range of cloths for which such raw materials could normally be used. Moreover, in fabrics made from coarser wool a small amount of hair would be less apparent, so that the sensitivity of the experiment as well would be appreciably reduced.

The wool finally selected for the test was classed as 48/50's (N.Z.) and was extracted from the fleeces of selected stud Romney ewe hoggets of the flock of Messrs. H. and M. Voss, of Karere. The hoggets were not shorn as lambs. The Voss flock is well known for the high standard of its wool, which has taken prizes in local and international competitions for Romney wool. Good environmental conditions of soil and pasture ensured that the wool was well grown, while the large number of stud sheep carried gave good scope for selection. The ready co-operation offered by Messrs. H. and M. Voss with any scheme of research, and the close proximity to Massey Agricultural College, made this flock a very satisfactory source of material. The wool characteristics of each sheep of the flock for count, length, character, and medullation had been examined and recorded periodically over a number of years by the staff at Massey College. From each of the selected animals which were classed within certain gradings of hairiness, 2½ lb. to 3 lb. of britch and hind-quarter wool were taken after the fleece had been skirted in the normal manner and before the wool was rolled. To make sure that the slight correlation existing in the fleeces between hairiness and low count did not interfere with the two lots for the test, a fleece sample was not consigned to either test lot until a sample for the other lot of corresponding fineness was found. This meant that a few of the finer samples from the line free from hair, and a few of the stronger samples from the hairy line, had to be discarded from the tests. The services of three wool-classers were used for this piece of work, as a result of which two very uniform lots of wool, A and B, each of 200 lb., were accumulated from the one shearing of the flock.

Unfortunately, the difference in degree of hairiness between the two test lots has proved to be rather smaller than was hoped for, despite the selection of britch and hind-quarter wool only. While this is disappointing, for it reduces the value of the test to the manufacturer, it must be reassuring to the New Zealand Romney breeder to know that, even when the worst portions of the skirted fleece were deliberately selected, the amount of hair present was negligible in a flock not greatly superior in hairiness to the standard set by all stud Romney sheep in the country. This statement acquires all the more force when it is realized that unshorn hoggets were used, and that the mob had not been culled, but contained substantially all the ewe lambs bred in the previous season. Nevertheless, there was a clearly-visible distinction between the two lots, and the difference was comparable with the variations to which attention has been drawn under the official fleece-testing scheme instituted at the Massey Agricultural College.

Some of the wool which had finally to be discarded from the two test batches differed only slightly from the main lots, and was suitable for collection into two small batches which served as pilot lots for the scouring and carding processes.

Analysis

Three representative staples from each sample put into the A and B test batches were extracted and bulked for hairiness, fibre length, and fineness determinations. These were degreased in warm benzene, and then, by repetition of a gentle hand drawing and doubling process, converted into slivers without fibre breakage being incurred. From the two slivers worsted draw samples were prepared for the hairiness estimations, transverse cuts of 2 mm. length were made for fineness measurement, and tong samples (Townend, 1938) taken for the determination of mean fibre length.

For hairiness estimation the photo-electric method developed by McMahon (1937) for routine tests was used on the samples. The instrument consists essentially of a system of illumination for the wool, lying immersed in a tray filled with benzene, and a simple optical arrangement which produces an image of the teased-out sample on the light-sensitive surface of a "blocking layer" photo cell. A small current is generated, and produces a deflection on a sensitive galvanometer. The instrument is standardized between readings against a grey enamel plate lying directly under the tray, and exposed to the lamps and cell when the tray is withdrawn to change the sample.

The degree of hairiness is read in centimeters on the galvanometer scale and, from the weight of the sample at 65 per cent. relative humidity, the deflection per gram of wool is calculated. An initial zero reading of 2 cm.* per gram is obtained on wool free from hair, and a reading of 100 cm. per gram corresponds to a sample of total hair. For samples such as those under consideration it can be assumed that the deflection per gram minus 2·0 is approximately equivalent to a percentage of coarse, hairy fibre which would have the same proportion, by volume, of medulla as the sample. All types of medulla—coarse and fine; continuous and discontinuous—are integrated and expressed in this one figure.

For fibre-fineness analysis the sampling and mounting method described by Stanbury and Daniels (1937) was adopted, using a Doehner lanameter of early design. Four separate slides were prepared from each of the two test lots, and five hundred fibres measured from each slide.

TABLE II.—HAIRINESS

A.		B.	
Sample.	Deflection, per Gram (cm.).	Sample.	Deflection, per Gram (cm.).
1	3·3	1	7·1
2	3·3	2	7·1
3	3·1	3	8·2
4	2·9	4	8·7
Mean	3·2	Mean	7·8
Percentage hairiness*	1·2	Percentage hairiness*	5·8

* Equivalent percentage of coarse, hairy fibre having the same proportion, by volume, of medulla.

For fibre-length determination six length biased samples extracted by the tong method were measured for each test lot, an average sample containing about one hundred and seventy fibres.

A summary of the results of the hairiness, fibre-fineness, and fibre-length determinations on the raw greasy wool are given in Tables II, III, and IV.

* In practice the readings for zero medullation fluctuate from about 1·9 cm./g. to about 2·3 cm./g., depending on the type of wool and the way it has been treated.

TABLE III.—FIBRE FINENESS

A.			B.		
Sample.	Mean Diameter. (μ).	Standard Deviation. (μ).	Sample.	Mean Diameter. (μ).	Standard Deviation. (μ).
1	34·3	8·5	1	33·1	9·2
2	32·5	8·1	2	33·8	9·7
3	33·7	10·7	3	33·5	8·5
4	33·8	9·1	4	32·8	7·9
Grand mean	33·6	9·2*	Grand mean	33·3	8·8*
Standard error	0·20		Standard error	0·20	

* R.M.S. of standard deviations.

TABLE IV.—FIBRE LENGTH

A.			B.		
Sample.	Mean Length (cm.)	Standard Deviation (cm.).	Sample.	Mean Length. (cm.).	Standard Deviation (cm.).
1	22·0		1	20·1	
2	23·1	±5·2	2	21·7	±5·9
3	23·4		3	22·4	
4	23·0		4	23·4	
5	23·1	6·0	5	20·2	5·7
6	22·7		6	21·5	
Grand mean	22·9	5·7*	Grand mean	21·5	5·8*
Standard error	0·2		Standard error	0·5	

* R.M.S. of standard deviations.

Statistical examination of the fineness results does not reveal any significant difference between A and B. The small difference in fibre length is just significant, A wool being slightly longer than B.

PROCESSING

Outline of Mill Trial

The quality of the wool severely limited the choice of fabrics which could be made; a finer wool would have offered a number of advantages and would have been of more practical interest to the New Zealand textile industry. After consultations with a number of people in the industry it was decided to make from each batch of wool a 2/2 twill navy-blue serge with a 2/26's warp and a 1/13's weft, it being considered that this would be a useful fabric, and that the making of it would provide a worth-while comparison of the properties of the two wools. It was also decided to make a small quantity of the wools into a 2/26's hosiery yarn and to have this made up into men's vest material.

Throughout the processing every endeavour was made to keep conditions as identical as possible for the two lots. Lot B followed immediately after Lot A on the same machines, apart from the piece scouring and dyeing, where they were handled together.

By means of humidification equipment it was possible to avoid large fluctuations in humidity during the carding, combing, drawing, and spinning. The average relative humidity and temperature were about 57 per cent. and 68° F. respectively. The humidity did not exceed 60 per cent., and was rarely, and then only for very short intervals, below 54 per cent. Wherever differences in processing properties could be expected, all relevant data were recorded.

Scouring

The wool was scoured in a three-bowl set and dried in a double-tier dryer. After the bowls had been made up with fresh liquors, 500 lb. of a good crossbred wool were passed through in order to get the baths in a satisfactory scouring condition. Before batch A was passed through the bowls, a pilot lot of about 50 lb. of closely-similar wool was scoured in order that any bits of wool remaining in the bowls or dryer from previous scourings might be picked up; similarly, a pilot lot preceded batch B, which was scoured immediately afterwards.

The scouring-bowl temperatures were 127° F., 123° F., and 110° F. respectively, and the approximate liquor concentrations were 0·2 per cent. soap and 0·1 per cent. soda in the first bowl, less than 0·05 per cent. soap and 0·05 per cent. soda in the second bowl, and the third bowl was a rinse bath. Excessive temperature in the dryer was avoided. After batch A had been scoured, small additions of soap and soda were added to the first bath. The yields from the two batches were closely similar and averaged 65 per cent. as calculated on the weights of the wool as they left the dryer.

Carding, Backwashing, and Combing

In emulsion form, 0·6 per cent. of Vacuum emulsion oil No. 1 was spread on the two batches and on the two pilot lots of scoured wool. This same emulsion was also used at later stages in the processing.

Prior to carding, the machine, a 1937 Haigh's crossbred card, was fettled and cleaned down. The pilot lot A was passed through, and the machine then again rubbed down and the floor swept before carding batch A. After the batch the card was fettled and the fettlings, sweepings, and burr beatings collected and weighed separately. A similar procedure was followed for batch B. The pilot lots were dispensed with at the card-sliver stage. The average carding output was 65 lb. to 70 lb. per hour, and in both cases a good clean sliver was produced. This was achieved despite the fact that the wool was a preparing and not a carding wool. The tendency of the feed rollers to choke due to the long wool limited the rate of feed.

All the machinery used after the card in the production of the singles and twisted yarn comprised a crossbred set manufactured by Prince, Smith, and Stells, Ltd. (1937).

The card sliver was backwashed in a two-bowl machine with average liquor temperatures of 115° F. and a drying temperature of 170° F. A 0·2 per cent. soap liquor was used in the first bowl and rinsing-water in the second, the bowls being made up fresh for each batch. The estimated amount of oil added after the dryer and prior to the backwash gill was only 0·3 per cent.

The slivers from the backwash gill were passed through one strong box and on to the punch box, where 6 lb. balls were made. In the combing, the feed knives were adjusted by hand, care being taken to record the settings and times, so as to make the same adjustments for the second batch. At the first finishing gill about 0·2 per cent. of oil was added to the combed sliver. From the second finishing gill a standard top sliver of 372 dr. per 40 yards was delivered, the balls weighing 8¾ lb.

Drawing and Spinning

After ten months' storage the tops were spun into 2/26's warp yarn, 1/13's weft yarn, and 2/26's hosiery yarn. The theoretical drafting data on which the actual drafts were based are given in Table V. A 6·3 dr. roving was made for the warp and hosiery yarn and an 8·3 dr. roving for the weft yarn.

TABLE V.—DRAFTING DATA

Operation.	Weight of Sliver fed to Machine (dr./40 yd.).	Number of Ends up.	Draft.
Can gill	372	5	6·75
Two-spindle gill	275	6	6·75
First drawing	244	6	8·5
Weigh box	172	6	9·0
First finisher	115	6	9·5
Second finisher	73	3	10·0
Reducer	22	3	10·2
Spinning 1/26's	6·5	1	..
First finisher	111	6	9·0
Second finisher	74	3	9·0
Reducer	25	3	9·0
Spinning 1/13's	8·3	1	..

Each machine was rubbed down prior to a batch going on, and after it had passed through; the fly and roller waste were collected.

About 0·3 per cent. of oil in emulsion form was added to the slivers behind the can gill.

In the spinning, the weft was spun on one side of a 180 spindle ring frame, while the hosiery yarn, followed by the warp yarn, was spun on the other. For both the hosiery and the warp yarn a number of ends-down tests for different periods were carried out. In sampling the yarns from the various batches for test requirements, bobbins from the same spindles were selected.

Weaving and Knitting

After twisting and winding and the usual operations for preparing the warp, the yarns were woven into two pieces on a Northrop automatic loom. A 15/16 oz. cloth was specified 56 in. wide, with a sett 24/4 (approximately 53 threads per inch) and 52 picks per inch. About 72 yards were woven from each batch of yarn. A record was kept of the warp breakages, and also data were collected of the amount of darning the two pieces required.

The A and B lots of hosiery yarn were each divided into two portions, a portion of A and one of B were knitted up and the fabrics finished by one firm, and the remainder by another. In each case a portion of the knitted fabric was left in the greasy state, some was scoured only, and the rest was made into finished garments.

Piece Scouring

The two pieces of woven fabric were scoured together in a piece-scouring machine, three scours being given, each in about 50 to 60 gallons of liquor. Brief scouring data are given in Table VI. After the warm rinse the pieces were cooled off and whizzed.

TABLE VI.—PIECE SCOURING

Scour.	Bath Strength.	Average Temp. (°F).	Time (Minutes).
1	0·1 per cent. ammonia ..	104	9
2	0·4 per cent. soap ..	105	13
3	0·2 per cent. soap ..	105	5
Rinse ..	..	110	20

Dyeing and Finishing

The two scoured pieces were each cut into three equal lengths, each third of A being stitched to a third of B. The three composite lengths were dyed in three separate dye baths according to the following dyeing formulæ :—

Dyeing 1 .. ..
- 10 per cent. Glaubers.
- 3 per cent. sulphuric acid.
- 5 per cent. erio navy blue AN.
- Brought to the boil in about ¾ hour and kept at the boil for 1 hour 20 minutes.

Dyeing 2 .. ..
- 3 per cent. metachrome.
- 4 per cent. coomassie navy blue 2RNS.
- Brought to the boil in about ¾ hour and kept at the boil for 1 hour 45 minutes.

Dyeing 3 .. ..
- 10 per cent. Glaubers.
- 4 per cent. coomassie navy blue 2RNS.
- Brought to the boil in about ¾ hour and kept at the boil for 1 hour 45 minutes.

After the pieces had been dyed, whizzed, tentered, and conditioned overnight, they were burled, brushed on the back, cropped and brushed on the face, Bailey blown, hydraulic pressed overnight, and then blown a second time.

The comparison of the effect of the different dyeings on the physical properties of the fabric is discussed on page 19.

RESULTS AND DISCUSSION

Carding and Combing

There were no marked differences detected between the carding performances of the two wools. The slight difference in degree of hairiness was evident between the slivers. The fettlings from the two lots and the sweepings from under the card as shown in Table VII were very similar in composition and weight, though after examination of the sweepings on the velvet board a marked difference was noticed between the bits left on the board when the bulk had been removed, B sweepings leaving behind far more short pieces of hair than A. A difference in hairiness was very evident between the burr beatings, but the larger quantity collected from lot A is difficult to account for.

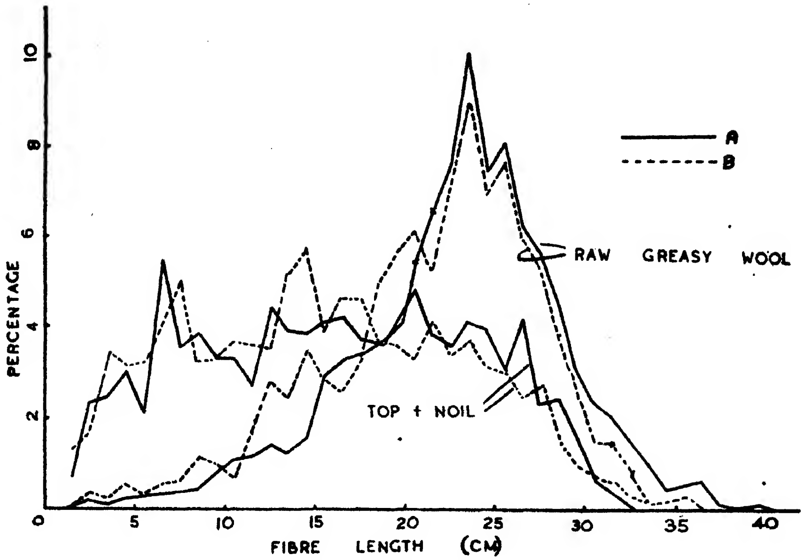

PERCENTAGE
10
8
6
4
2
0
5
10
15
20
25
30
35
40
FIBRE LENGTH (CM)
A
B
RAW GREASY WOOL
TOP + NOIL

FIG. 2.

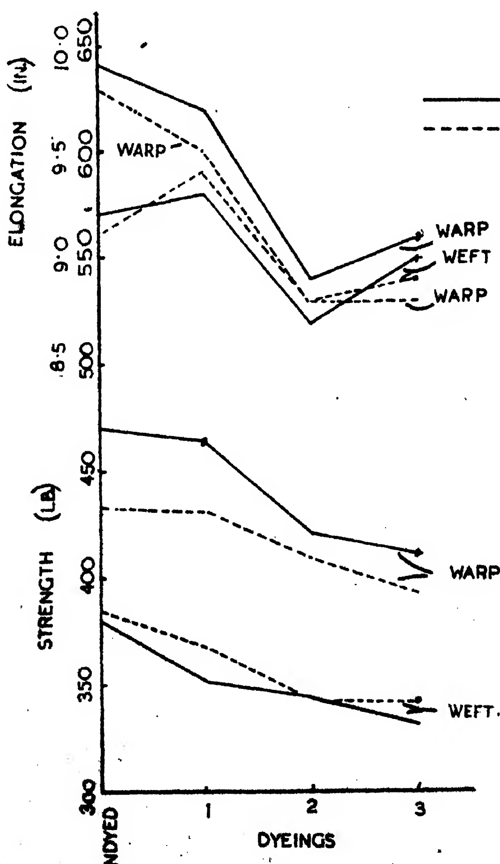

ELONGATION (IN)
10·0
9·5
9·0
8·5
650
600
550
500
450
400
350
300
STRENGTH (LB)
A
B
WARP
WARP
WEFT
WARP
WARP
WEFT.
UNDYED
1
2
3
DYEINGS

FIG. 3

TABLE VII.—SCOURING, CARDING, AND COMBING

Material.	Weights. A.	Weights. B.
	lb. oz.	lb. oz.
Greasy wool	198 0	203 0
Scoured wool	128 0	133 0
Fettlings (from dryer)	9 3	8 8
Sweepings	5 5	6 4
Burr beatings	0 6	0 1½
Top	113 5	119 8
Noil	4 14	5 0
Tear	23·3	23·9

No differences were observed in the processing of the two lots either on the comb or on the finishing gills. Results of the fibre-length analyses of the tops reveal no significant difference between them, as shown in Table VIII.

TABLE VIII.—FIBRE LENGTH OF TOP

A. Sample.	A. Mean Length (cm.).	A. Standard Deviation (cm.).	B. Sample.	B. Mean Length (cm.).	B. Standard Deviation (cm.).
1	15·1	7·1	1	14·4	7·1
2	16·1		2	14·7	
3	14·4		3	15·7	
4	19·1	7·4	4	15·7	7·4
5	16·2		5	16·3	
6	16·9		6	18·1	
Grand mean	16·3	..	Grand mean	15·8	..
Standard error	0·7		Standard error	0·6	

The length of the noils compared very closely, the mean lengths of true samples (as distinct from the length-biased samples taken from the raw greasy wool and top) being 3·0 cm. and 2·8 cm. for A and B respectively. For these measurements, fibres below 1 cm. in length in the samples, which were approximately 10 per cent. of the total number of fibres for each lot, were not included.

By conversion of the length frequencies of the true samples of the noil to those of length-biased samples, as explained in a previous paper (Townend, 1938), composite curves for the frequency distribution of the combined top and noil could be drawn. These curves are plotted and compared with those for the raw greasy wools in Fig. 2 in order to show the extent of the fibre breakage in the conversion of the wool to top. The degree and type of damage the two wools suffered are shown to be closely similar.

Representative samples in duplicate were taken from top and noil of both A and B lots and measured for hairiness in an endeavour to find if there was any evidence of the hairy fibres having suffered more breakage than the wool fibres. It is considered that the differences between the mean results of the tops and their respective noils are not large enough to warrant any comment (Table IX).

TABLE IX.—HAIRINESS

Sample.	A: Deflection, per Gram (cm.).	B: Deflection, per Gram (cm.).
Top	2·6	6·2
Noil	3·6	6·8

Drawing and Spinning

Through the drawing, both wools processed equally satisfactorily. There did not appear to be any specially-large differences in the hair content of the fly and roller waste collected from the various boxes for the two batches. In all cases the quantity of waste was small, as indicated in Table X. While the weights given must be regarded as very approximate, the general indication is that B lot made slightly more fly and roller waste than A.

TABLE X.—FLY AND ROLLER WASTE

—	A (g.).	B (g.).
Spindle gill	4	5
Weigh box	4	4
First finisher	4	11
Second finisher	13	25
Reducer	10	24
Spinning—		
Weft	28	18
Warp	15	30
Hosiery	4	8

For the spinning trials, a summary of which is given in Table XI, the hosiery and warp yarns were concentrated upon. It was found that 1/26's counts was near the spinning limit of the roving, which made it unnecessary to spin, as was originally intended, a fine count solely for the purpose of an ends-down test. In recording ends down, only those were counted where the breakage was due to a weak place—a number of ends broke due to snarling, and others were accidentally knocked down during piecening. The results show a slight and yet consistent difference in favour of the A yarns. Results of tests on yarn from bobbins taken to represent the different spins (see Tables XII and XIII) suggest that with both the warp and hosiery yarns the mean counts of the A yarns were slightly heavier than those of the B. If this were so, the small difference could possibly account for the slightly better spins of the A yarns.

TABLE XI.—SPINNING TRIALS

Yarn.	A. Time Period (Minutes).	A. Ends down per Minute during Period.	B. Time Period (Minutes).	B. Ends down per Minute during Period
Hosiery	5	1·82	11	1·73
	10	0·80	5	1·40
	18	0·72	18	1·56
	70	0·87	54	0·93
	103	0·89	88	1·18
Warp	11	0·45	132	0·43
	37	0·51	60	0·40
	29	0·48	24	0·46
	35	0·20	20	0·70
	135	0·47	25	0·48
	25	0·32	60	0·63
	60	0·20	120	0·57
	332	0·39	441	0·51

For each of the single yarns twenty strength tests were made on each of four bobbins, and forty twist tests were made on each of four bobbins for the warp yarns and on each of two bobbins for the other single yarns. For the twofold yarns only half the number of bobbins were tested. The twist determinations were made on successive 1 in. lengths, while the strength-test pieces were 18 in. long, and 1 yard was wasted between each test length.

TABLE XII.—HOSIERY YARN

—	Hosiery Singles. A.	Hosiery Singles. B.	Hosiery Twofold. A.	Hosiery Twofold. B.
Mean count	26·2	26·9	13·2	13·5
Mean yarn strength (oz.) ..	3·4	2·9	13·6	12·1
Coefficient of variation of strength, V_s (per cent.)	34·3	44·8	13·9	16·5
Mean elongation (per cent.) ..	9·7	9·7	13·3	12·3
Mean strength count product ..	88·9	76·4	179·7	163·6
Mean hank strength (lb.) ..	24·0	22·5	89·0	82·5
Mean twist (T.P.I.)—				
"Z" twist in singles	7·6	7·5	5·5	5·3
"S" twist in twofold ..	..	..	..	..
Coefficient of variation of twist, V_t (per cent.)	28·1	35·5	19·4	21·4

TABLE XIII.—WARP YARN

—	Warp Singles. A.	Warp Singles. B.	Warp Twofold. A.	Warp Twofold. B.
Mean count	26·3	27·0	13·1	13·2
Mean yarn strength (oz.) ..	4·3	4·4	16·3	15·2
V_s (per cent.)	27·7	25·0	10·0	9·1
Mean Elongation (per cent.) ..	10·4	11·2	17·8	18·8
Mean strength count product ..	113·4	118·2	213·0	200·0
Mean hank strength (lb.) ..	31·8	29·1	103·0	96·5
Mean twist (T.P.I.)—				
"Z" twist in singles ..	9·0	9·7	8·1	7·7
"S" twist in twofold ..	..	..	..	..
V_t (per cent.)	26·4	28·5	14·4	14·3

TABLE XIV.—WEFT YARN

—	Weft Singles. A.	Weft Singles. B.
Mean count	13·7	13·3
Mean yarn strength (oz.) ..	9·0	9·6
V_s (per cent.)	18·7	14·8
Mean elongation (per cent.) ..	13·1	13·5
Mean strength count product ..	122·9	128·1
Mean hank strength (lb.) ..	66·1	68·2
Mean "Z" twist (T.P.I.) ..	5·8	6·2
V_t (per cent.)	19·5	22·3

In comparing the strength of the yarns, preferably by comparing the mean strength count product figures (see Tables XII, XIII, and XIV), there is no consistent difference in favour of either of the wools. If the fibres in the wool of one batch had been stronger than those in the other, this would have been reflected at least in the strength of the respective warp yarns, while any difference in the surface conditions or the length of the fibres would have shown up more in the softly-twisted weft and hosiery yarns. The only differences in strength which approach significance are those for the hosiery yarns, both the single and twofold yarns of A being slightly stronger than those of B. The differences in the results of the hank tests, which were made on 90-yard hanks wound on a 1½-yard reel, are in close accord with those of the single-thread tests. There are no significant differences shown in the elongation of the yarns.

As shown by the coefficients of variation of the strength and twist results, the hosiery and warp yarns especially were very uneven, presumably because the wool had been spun near to its limit. Although the two carrier rollers in the drawing-boxes were set as carefully as possible, the unevenness was also possibly due in part to insufficient fibre control during drafting of the wool of such widely-varying fibre lengths. There is no consistent difference between the degrees of levelness of the A and B yarns.

Knitted Fabric

The hosiery yarns sent to one firm were knitted up on the frame, and those sent to the other on the circular machine. With the frame-knitted material the A fabric was noticeably more uneven than B. This was surprising, since of the yarns tested the coefficient of variation of both the strength and twist results showed B to be the more uneven yarn. There was no distinctive difference in appearance of the fabrics knitted on the circular machine.

It was considered that the extra unevenness in appearance of the A frame-knitted fabric was probably an indication that A yarn was slightly stiffer than B, which with the frame stitch accentuated the unevenness caused by the yarn irregularity. Any differences there were in handle were very fine ones, for although some people were consistent in claiming A fabric as very slightly softer than B, other judges were equally consistent in selecting B as the softer. Attempts were made in comparing handle to consider separately the light surface touch and the feel of the body of the fabric. Although slightly more hairy fibres could be recognized on the surface of the B fabrics, there was not evidently a sufficient amount to effect a detectable difference to the touch.

The mean results of shrinkage tests (B.S.I. Tentative Standard, 1939) which were carried out in duplicate on scoured vests from A and B yarns knitted at the two firms are given in Table XV. They show that the shrinkage properties of the two wools were closely similar. The felted samples were very similar in handle and colour.

TABLE XV.—SHRINKAGE TESTS

Machine.	Reduction in Area (Percentage).	
	A.	B.
Frame	35	29
Circular	25	32
Mean	30	30·5

Any slight differences there may have been suggested the A test pieces as slightly softer and creamier than the B ones.

Weaving, Darning, and Finished Cloth

There was a marked difference in the weaving performance of the two warps in favour of B, as shown in Table XVI. This is in contrast with what might have been expected after the spinning trials. With both warps more ends broke during the early period of the weaving than later on.

TABLE XVI.—WEAVING PERFORMANCE

A.		B.	
Total Picks.	Warp Breakages.	Total Picks.	Warp Breakages.
134,300	172	136,000	34
Picks per warp breakage = 780		Picks per warp breakage = 4,000	

Any slight difference there is in warp yarn irregularity as shown by variations in the strength results (see Table XIII) is also in favour of B yarn. No record was kept of weft breakages, though the general impression of the weaver was that B pieces wove appreciably better than A.

The difference in weaving performance of the two pieces was naturally reflected in the amount of darning found necessary, as shown in the summary of a specially-kept darner's record (Table XVII).

TABLE XVII.—DARNING

—	A.	B.
Thick threads	103	84
Knots	500	400
Darns	189	60
Time (hours)	$15\frac{1}{2}$	11

Despite three different comparisons of the A and B wools in finished woven material, there being three pairs of differently-dyed fabrics in addition to the comparison of the undyed fabric, not one difference in handle or appearance was detected, by the many people who judged, which could

definitely be associated with the difference in hairiness. In all cases, as with the knitted fabrics, the A and B materials compared very closely. A number of people (probably in the majority) thought A fabrics were generally slightly harsher, but others were consistent in making an opposite decision. On the A fabrics there did appear a slight indication of the weft streakiness being more irregular and therefore more pronounced than on the B fabrics.

With none of the three types of dyeing was the difference in the dyeing properties of the medullated, as compared with the non-medullated, fibres sufficient to make a detectable difference between the B fabrics, with their approximately 4 per cent. of hairy fibres, and the A fabrics, almost free of hair (*cf.* Table IX). No marked difference could even be discerned when the fabrics were examined under a low-power magnifying-glass used for examination of cloth structure.

A number of standard test pieces 6⅝ in. wide (frayed width) taken from the undyed and finished cloth were tested for strength and elongation on the Goodbrand's machine (see Tables XVIII and XIX). From each piece of cloth five test samples from positions distributed across the full width of the fabric were tested warpwise and eight test pieces covering four different lots of weft threads were tested weftwise. Only the means are given of each group of two weft samples, since they included the same lot of weft threads at different positions across the piece.

TABLE XVIII.—CLOTH TESTS: STRENGTH

Material	Warpwise.		Weftwise.	
	A (lb.).	B (lb.).	A (lb.).	B (lb.).
Undyed, scoured only	..	433	375·5	380
	478	442	383	392
	478	427	383·5	382
	462	434	383	387·5
	471	428	..	..
Mean	472	433	381	385
Dyeing 1	453	428	358	377·5
	466	425	352	385
	455	425	353	360·5
	479	448	345	349
	471	434	..	..
Mean	465	432	352	368
Dyeing 2	419	408	342	348
	420	403	350	355
	416	398	341·5	331
	426	422	341	337·5
	429	422	..	..
Mean	422	411	344	343
Dyeing 3	396	398	340	350·5
	398	389	333	352
	402	387	325	331
	430	408	335	339·5
	432	387	..	..
Mean	412	394	333	343

TABLE XIX.—CLOTH TESTS: ELONGATION*

Material.	Warpwise.		Weftwise.	
	A (in.).	B (in.).	A (in.).	B (in.).
Undyed; scoured only	..	9·9	9·2	9·0
	10·0	10·2	9·45	9·0
	9·9	9·9	9·2	9·1
	9·9	9·6	9·15	9·2
	10·0	9·6	..	..
Mean	9·9	9·8	9·2	9·1
Dyeing 1	9·7	9·5	9·5	9·35
	9·7	9·5	9·0	9·5
	10·0	9·7	9·5	9·6
	9·5	9·5	9·2	9·1
	9·4	9·2	..	..
Mean	9·7	9·5	9·3	9·4
Dyeing 2	8·9	8·4	8·6	8·65
	9·2	8·9	8·5	8·65
	9·0	8·7	8·7	8·95
	8·7	9·0	9·0	8·95
	8·7	8·9	..	..
Mean	8·9	8·8	8·7	8·8
Dyeing 3	9·2	8·7	9·0	9·0
	9·2	9·0	9·0	9·0
	9·2	8·5	8·9	8·75
	8·9	9·0	8·95	8·8
	9·0	8·7	..	..
Mean	9·1	8·8	9·0	8·9

* The results given are those recorded from the machine and are the total extended lengths of the test pieces at rupture; the initial distance between the grips is 6⅜ in.

It will be noted that the last two warp-strength results for the six dyed lengths are in most cases significantly higher than those of the other test. The high results relate to test pieces which were taken from similar positions in all the fabrics—about one-third and two-thirds across the piece—and were prepared and tested at a later date than the other test pieces. While it is difficult to account for this increased strength, fortunately the abnormality does not interfere with the conclusions as it affects A and B similarly.

Warpwise the fabrics A are significantly stronger than fabrics B. Referring back to Table XIII, it will be seen that any difference suggested by the strength results of the twofold yarns is in accord with the cloth strength figures. Weftwise there is no significant difference between the A and B fabrics, any difference which might be suggested would make B slightly stronger, again being supported by the single thread strength results (see Table XIV). There are no significant differences in elongation between the A and B fabrics, as shown in Table XIX. For either warp or weft what differences there are in cloth strength are small and based on the relatively few bobbins used for count determination; it is not possible with the information available to dissociate any difference there is from a probable slight difference in mean count.

Influence of Different Dyeings on the Physical Properties of the Fabric

In addition to the study of the effect of the different dyeings on the non-hairy fabrics, advantage was taken to compare the effect of the different dyeings (see page 10) on the same fabric. It should be noted that all dyeings were navy blue. The results of the strength and elongation tests made on the fabrics which are given in Tables XVIII and XIX are summarized in Fig. 3.

The undyed fabric is shown to be slightly stronger in both warp and weft than any of the dyed fabrics. From the results and the diagram it is evident that, with reference to fabric strength and elongation, dyeing 1—that is, acid dyeing—caused less damage to the wool than either of the other two dyeings (dyeing 2 with a metachrome bath, and dyeing 3 with a neutral liquor). Placing the dyeings in order of fabric strength they are: Dyeings 1, 2, and 3 respectively. The curves of the elongation results are of interest in that they show a significant difference between the elongation at break of the fabric of dyeing 1 and of the other two dyed fabrics. In comparing the handle of the three fabrics the chief difference was that the acid-dyed fabric felt slightly stickier than the other two, or, expressed another way, the metachrome- and neutral-dyed fabrics felt silkier than the acid-dyed fabric. It is possible that this difference in handle is related to the difference in elongation of the fabrics. For superiority of handle the fabrics were placed in the following order: Dyeings 3, 2, and 1 respectively, though 3 and 2 were very similar.

CONCLUSIONS

The presence of medullation equivalent to about 6 per cent. of coarse, hairy fibre does not appreciably affect the processing properties of sound, well-grown Romney wool of 48/50's quality (mean fineness. 3μ).

This amount of hairiness, although clearly visible in bulked raw material, produced no marked differences in the appearance and handle of either woven or knitted fabrics; nor could it be detected in finished cloths dyed navy blue in either an acid or a neutral bath. Throughout the mill trial there was no indication of any differences, with marked industrial significance, between the pure wool fibres grown on non-hairy fleeces and on fleeces containing medullation equivalent to 6 per cent. of coarse, hairy fibre.

While the small difference in hairiness between the two lots reduces the value of the test to the wool-manufacturer, it establishes that even the most hairy portions of the fleeces clipped from a mob of seven hundred unculled stud Romney ewe hoggets, not shorn as lambs, do not contain a serious amount of medullated fibre after the fleeces have been skirted in the normal manner.

It should be reiterated that this work is intended to be only a preliminary investigation and must eventually embrace different degrees of hairiness and different classes of wool, especially those of finer quality. The test has demonstrated the unique opportunities available in New Zealand for research work in which the interrelationships between the problems of the wool-producer and those of the wool-manufacturer can be studied.

ACKNOWLEDGMENTS

Thanks must first be accorded to the New Zealand Wool Council, by whose grant the investigation was made possible, and to the Committee of the Wool Manufacturers' Research Association for its permission to carry out and report this work. The generous co-operation of Messrs. H. and M. Voss and of the Timaru Worsted and Woollen Co., Ltd., has been greatly appreciated. Special thanks are due to the staff of the Massey Agricultural College fleece testing and recording department, and to members of the staffs of the Wool

Manufacturers' Research Association and the Wool Metrology Laboratory, Canterbury Agricultural College, without whose assistance this test could not have been carried out.

REFERENCES

B.S.I. Tentative Standard (1939): *J. Textile Inst., 30,* s22–8.
ELPHICK (1932): *J. Textile Inst., 23* T367.
LANG (1942): "Report to the Australian Wool Board from the Gordon Institute of Technology."
McMAHON (1937): *J. Textile Inst., 28,* T349.
SIDEY (1931): *N.Z. Dept. S. & I. R., Bull. 30.*
STANBURY and DANIELS (1937): *J. Textile Inst., 28,* T188.
TOWNEND (1938): *J. Textile Inst., 28,* T55.
WATERS (1935): *Massey Ag. Coll. Bull. No. 4.*

TOP-DRESSING AND PROVISION OF WINTER FEED IN RELATION TO DAIRY PRODUCTION

By W. M. HAMILTON, Department of Scientific and Industrial Research, Wellington

Summary

The correlation between the area cut for hay and silage and dairy production in the following season over the period 1930–43 is shown to be $r = +0{\cdot}77$ for the Dominion as a whole or $r = +0{\cdot}78$ for Auckland Province. A similar close relationship does not exist between area top-dressed and dairy production. The implications of the above correlations are briefly discussed and an attempt made to account for annual variations in the area top-dressed or cut for hay and silage.

INTRODUCTION

IN an earlier paper(1) attention has been directed to the close correlation between the area of grasses and clovers cut for hay or silage and dairy production in the following season. A similar relationship does not appear to exist between the area of grassland top-dressed with fertilizers or lime, though obviously the area which can be saved as hay or silage must partly depend on the productivity of pastures, which in turn is influenced by their previous manurial treatment. In view of the present need for increased dairy production, the above relationships become of considerable practical importance, and the available data have therefore been examined in more detail and are presented below.

AREA TOP-DRESSED

Statistics of the area of grassland top-dressed were first collected in the 1926–27 season. In this and the following season data were collected as to the area top-dressed with different types of fertilizers—*e.g.*, superphosphate, slag, &c., and lime. The actual area top-dressed, however, cannot be determined, since much of the lime would be applied to areas also receiving phosphate. This defect in the statistics was remedied in 1928–29 by collection of the "actual area top-dressed" (including lime). As an economy measure agricultural and pastoral statistics were collected by post in 1930–31 and 1931–32 and the collection form considerably simplified. For these two years data on top-dressing were collected under two headings: "Area of grassland top-dressed with artificial fertilizers once or more during period," and "Area of grassland top-dressed with lime." Due to overlapping of areas, these cannot be added to determine the "total area top-dressed." This position was rectified in 1932–33, and since that date the position is quite clear. In the table below an attempt has been made to reconcile the

available statistics over the period 1926–27 to 1931–32 with those for the following seasons, estimated figures being shown in italics :—

TABLE I.—AREA OF GRASSLAND TOP-DRESSED WITH FERTILIZERS OR LIME IN THE DOMINION DURING THE PERIOD 1926–27 TO 1942–43

Season.	A. Top-dressed with Fertilizer (alone or plus) Lime) (Thousand Acres).	B. Top-dressed with Lime (alone or plus Fertilizer) (Thousand Acres).	C. Top-dressed with Lime alone (Thousand Acres).	D = A + C. Total Area top-dressed with Lime or Fertilizer (Thousand Acres).	Column C as a Percentage of Column B.	Area limed as a Percentage of Total Area top-dressed.
1926–27	1,410	107	*16*	*1,426*	*14·8*	7·5
1927–28	1,831	118	*17*	*1,848*	*14·8*	6·4
1928–29	*2,352*	223	*33*	2,385	*14·8*	9·4
1929–30	*2,598*	360	*53*	2,651	*14·8*	13·6
1930–31	2,432	439	*65*	*2,497*	*14·8*	17·6
1931–32	2,068	387	*57*	*2,125*	*14·8*	18·2
1932–33	2,335	697	103	2,438	14·7	28·6
1933–34	2,133	780	116	2,249	14·9	34·7
1934–35	2,538	981	146	2,684	14·9	36·5
1935–36	2,731	1,084	151	2,882	13·9	37·6
1936–37	3,149	1,204	177	3,326	14·7	36·2
1937–38	3,685	1,358	189	3,874	13·9	35·0
1938–39	3,798	1,432	218	4,017	15·2	35·7
1939–40	3,983	1,423	204	4,187	14·3	34·0
1940–41	4,398	1,724	251	4,649	14·6	37·1
1941–42	3,832	1,888	380	4,212	20·1	44·8
1942–43	2,899	1,895	571	3,470	30·2	54·5

The estimates were computed by expressing the area receiving lime alone (column C) as a percentage of the total area limed (column B). This figure remained remarkably constant until the commencement of fertilizer rationing in 1941, and it was therefore considered a reasonable assumption to take the average of the three years 1932–33 to 1934–35 and apply it to the previous seasons. Similar corrections were applied to the individual land districts in the North Island, and these data will be presented later.

The area of grassland top-dressed with artificial fertilizers in 1940–41 was 69 per cent. greater than in 1929–30, the highest peak reached before the depression. Over the same period the area top-dressed with lime increased nearly fivefold (480 per cent.), but most of this lime was applied on areas also receiving artificial fertilizer, only some 5 per cent. of the total area top-dressed receiving lime alone. Since the introduction of fertilizer rationing the area receiving lime alone has naturally shown a marked increase.

DAIRY PRODUCTION

Detailed estimates of total production of butterfat "at the pail" are compiled annually by the Statistical Section of the Department of Agriculture for the Dominion as a whole, and these estimates have been used in earlier papers(1, 2). Unfortunately, similar data are not available on a land-district or provincial basis. The only published figures of dairy production available on a provincial basis are those provided by "Statistics of Factory and Building Production" of butterfat supplied to dairy factories in the years ending 31st March. Such data are not entirely satisfactory, since production from parts of two producing seasons are included in the one year. Since, however, only approximately 10 per cent. of production in a "normal" season occurs subsequent to 31st March, the figures are unlikely to introduce any serious anomalies. Data covering the normal "producing" season not being available, that from "Statistics of Factory and Building Production" covering the year ending 31st March has been used in this analysis unless otherwise stated.

Factors affecting Dairy Production

The reconciliation of top-dressing data noted above has somewhat modified, but not materially altered, the relationship with dairy production,

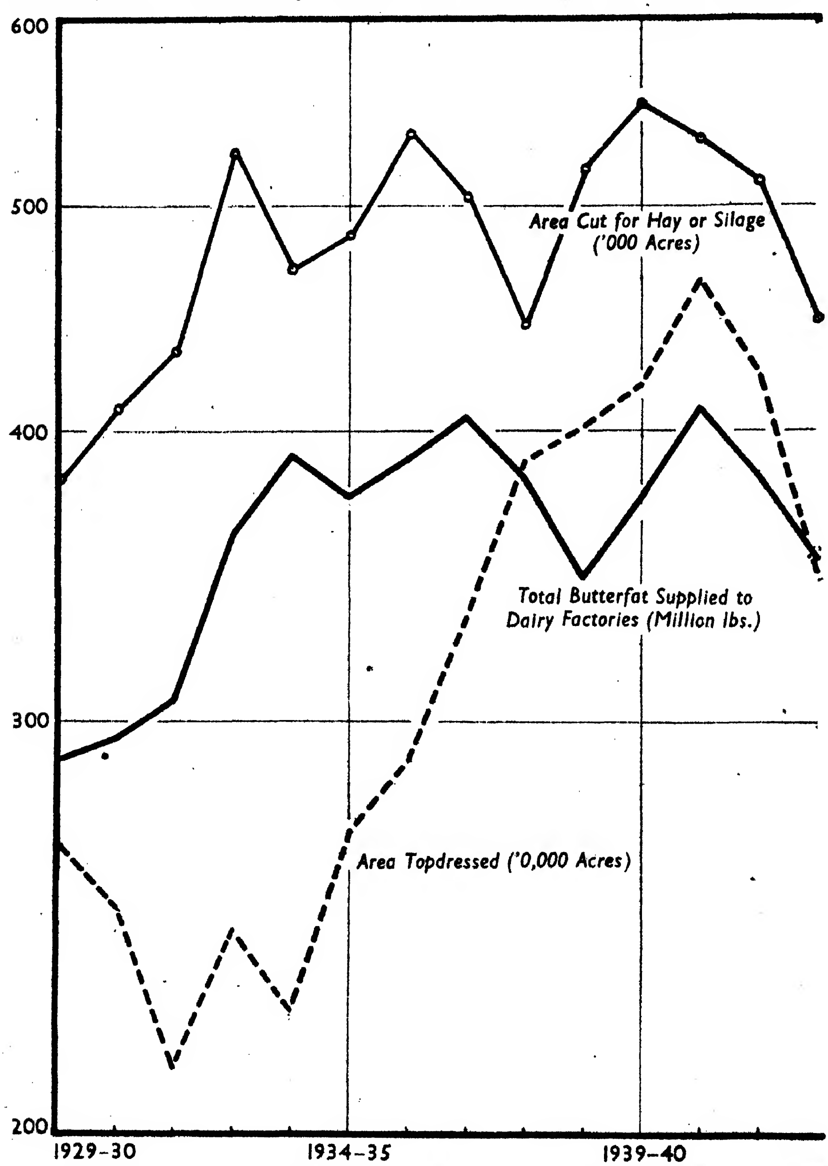


FIG. 1.—Data for the Dominion as a whole showing the total area of grasses and clovers cut for hay or silage, the total area of grassland top-dressed with fertilizers or lime, and the total amount of butterfat supplied to dairy factories in the years ending 31st March. Note the fall in area top-dressed during the years 1930–34 and the rapid rise in dairy production during the same period; also the close correspondence between hay and silage saved in one season and dairy production in the year following (semi-logarithmic base).

to which attention has already been directed (1, 2). The data for the Dominion are shown in Fig. 1, which clearly illustrates the close relationship between the area of hay and silage saved in any season and dairy production in the

following season. It also emphasizes the absence of any similar close relationship in the case of area of grassland top-dressed and dairy production. Detailed figures are presented in Table II.

TABLE II

Season.	Total Area cut for Hay or Silage (Thousand Acres).	Total Area top-dressed with Lime or Fertilizer (Thousand Acres).	Number of Cows in Milk at 31st January (inclusive of Stock in Boroughs).	Total Butterfat supplied to Factories Year ending 31st March (Thousand Pounds).	Effective Average Production per Cow (Pounds Butterfat).	Area cut for Hay or Silage per One Thousand Cows (Acres).	Area of Hay or Silage cut in Previous Season per 100,000 lb. Butterfat (Acres).	Area top-dressed with Fertilizers or Lime. Per One Hundred Cows (Acres).	Area top-dressed with Fertilizers or Lime. Per 10,000 lb. of Butterfat. (Acres).
Dominion									
1928–29	320	2,385	1,291,204	257,996*	199·8	248	..	185	92·4
1929–30	381	2,651	1,388,872	288,462*	207·7	274	111	191	91·9
1930–31	409	2,497	1,499,532	294,363	196·3	273	129	167	84·8
1931–32	432	2,125	1,582,664	305,993	193·3	273	134	134	69·4
1932–33	526	2,438	1,723,913	361,597	209·8	305	119	141	67·4
1933–34	470	2,249	1,816,402	390,498	215·0	259	135	124	57·6
1934–35	485	2,684	1,827,962	375,194	205·3	265	125	147	71·5
1935–36	536	2,882	1,823,358	389,281	213·4	294	125	158	74·0
1936–37	504	3,326	1,805,405	405,460	224·5	279	132	184	82·0
1937–38	444	3,874	1,763,775	381,370	216·2	252	132	220	101·6
1938–39	518	4,017	1,744,478	345,738	198·2	297	128	230	116·2
1939–40	554	4,187	1,739,874	374,916	215·5	318	138	241	111·7
1940–41	534	4,649	1,779,603	409,252	230·0	300	135	261	113·6
1941–42	513	4,212	1,777,239	382,285	215·1	289	140	237	110·2
1942–43	447	3,470	1,735,444	352,290	203·0	258	146	200	98·5
Auckland Province (North Auckland, Auckland, and Gisborne Land Districts (excluding Wairoa County))									
1928–29	150	1,263	614,361	126,385*	205·7	244	..	206	100·0
1929–30	204	1,396	678,549	148,421*	218·7	301	101	206	94·0
1930–31	209	1,347	753,096	151,141	200·7	277	135	179	89·1
1931–32	243	1,262	809,288	163,584	202·0	301	128	156	77·2
1932–33	273	1,378	894,568	199,795	223·3	305	122	154	69·0
1933–34	255	1,337	954,486	214,541	224·8	267	127	140	62·3
1934–35	258	1,464	977,938	211,416	216·2	264	121	150	69·3
1935–36	285	1,569	994,710	220,962	222·1	287	117	158	71·0
1936–37	269	1,758	997,444	233,045	233·6	269	122	176	75·4
1937–38	239	1,915	988,204	219,314	221·9	242	123	194	87·3
1938–39	252	1,961	991,848	197,357	199·0	254	121	198	99·4
1939–40	310	2,074	986,547	221,405	224·4	314	114	210	93·7
1940–41	278	2,237	1,027,651	246,448	239·8	271	126	218	90·8
1941–42	259	2,066	1,028,627	225,367	219·1	252	123	201	91·7
1942–43	233	1,759	1,005,967	204,727	203·5	232	127	175	85·9
Taranaki Province (including Patea County)									
1928–29	58·4	318	199,439	43,623*	218·7	293	..	159	72·8
1929–30	61·2	354	209,163	48,499*	231·9	293	120	169	72·9
1930–31	68·2	333	220,213	50,538	229·5	310	121	151	65·9
1931–32	74·7	300	225,566	49,516	219·5	331	138	133	60·5
1932–33	86·2	347	239,204	55,901	233·7	360	134	145	62·1
1933–34	79·0	287	248,131	60,406	243·4	318	143	116	47·5
1934–35	80·1	330	249,512	58,195	233·2	321	136	132	56·7
1935–36	89·3	356	248,544	59,420	239·0	359	135	143	59·9
1936–37	81·6	404	246,347	60,920	247·3	331	147	164	66·3
1937–38	81·5	442	241,352	61,553	255·0	338	133	183	71·8
1938–39	87·3	448	239,758	55,095	229·8	264	148	187	81·3
1939–40	88·0	469	243,994	59,687	244·6	361	146	192	78·6
1940–41	86·6	490	248,124	63,617	256·4	349	138	197	77·0
1941–42	84·6	431	246,734	59,439	240·9	343	146	175	72·6
1942–43	75·9	367	240,602	58,942	245·0	316	144	152	62·2

* These two years include whey fat purchased from other factories.

A clearer picture of the relationships shown in Fig. 1 may be obtained by comparing the fluctuations in area top-dressed or in area cut for hay or silage with fluctuations in the production of butterfat, and the data are presented in this form in Table III :—

TABLE III.— INCREASES (+) OR DECREASES (—) OVER THE PREVIOUS SEASON IN THE AREA CUT FOR HAY OR SILAGE, BUTTERFAT SUPPLIED TO DAIRY FACTORIES, AND AREA OF GRASSLAND TOP-DRESSED OVER THE PERIOD 1930–43

(The data for hay and silage have been carried forward one year so that they coincide with the production which they influence)

Season.	Variation in Area cut for Hay and Silage (Thousand Acres).	Variation in Butterfat supplied to Dairy Factories (Millions Pounds).	Variation in Area of Grassland top-dressed (Thousand Acres).
1930–31	+61	+ 6	−154
1931–32	+28	+12	−372
1932–33	+23	+55	+313
1933–34	+94	+29	−189
1934–35	−56	−15	+435
1935–36	+15	+14	+198
1936–37	+51	+16	+444
1937–38	−32	−24	+548
1938–39	−60	−36	+143
1939–40	+74	+29	+170
1940–41	+36	+34	+462
1941–42	−20	−27	−437
1942–43	−21	−30	−742

Over the fourteen-year period 1930–43 the movement of area cut for hay or silage has consistently forecast the trend of dairy production in the following year. A direct correlation between the total area cut for hay and silage and total dairy production in the following season gives a value of $r = +0{\cdot}91$. The high correlation obtained is not considered to be a true reflection of the influence of area cut for hay and silage on production, since it fails to make any allowance for the large volume of production which would be maintained even if no hay or silage were saved. The position appears to be more correctly portrayed by correlating the fluctuations in area cut for hay and silage with fluctuations in dairy production in the following season, as shown in Table III. When this is done, $r = +0{\cdot}77$, which is significant at the 1-per-cent. level. Stated in other terms, 60 per cent. of the seasonal variance in dairy production is associated with changes in the area cut for hay and silage in the previous season.

Using the same method of computation, the correlation between area top-dressed and dairy production over the period 1930–43 is $r = +0{\cdot}30$, which is not significant at the 5-per-cent. level.

The objection may be raised that all hay and silage is not fed to dairy stock, nor is all top-dressing applied to dairy pastures. Both objections are valid, though there appears no ready method of determining from existing statistics in what degree they influence the relationship noted above. Indirect evidence on the validity of the conclusions may be obtained, however, from several angles.

The first and obvious test is to ascertain whether the relationships shown for the Dominion as a whole apply in primarily dairying districts, such as Auckland and Taranaki Provinces. Figure 2 shows the data for Auckland Province over the period 1929–30 to 1942–43. As in the case of the Dominion data, in no season has the movement of area cut for hay and silage failed to forecast correctly the trend of dairy production in the following season, the correlation being $r = +0{\cdot}78$.

The question naturally arises as to why the correlation should be between *total* area cut for hay and silage and *total* butterfat-production, rather than between area of hay and silage *per cow* and production *per cow*. The correlation in the latter case ($r = +0{\cdot}63$) may be disturbed by the rapid

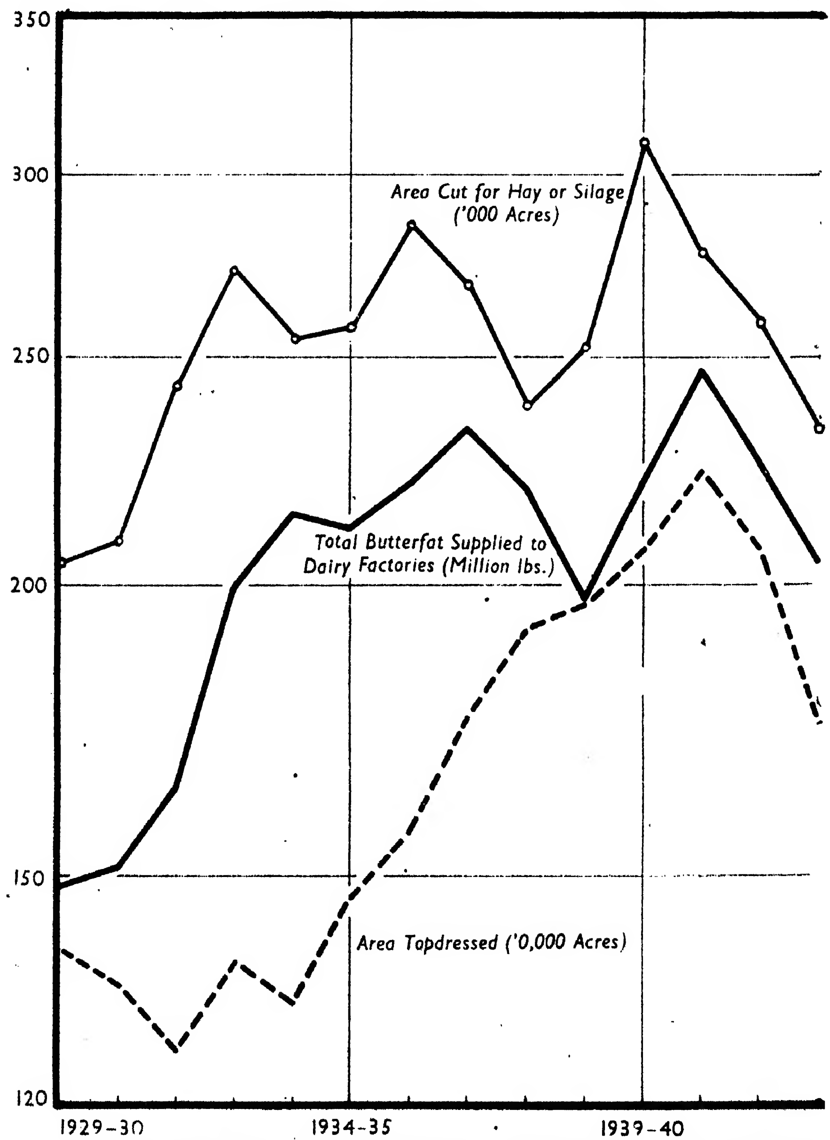


FIG. 2.—Data for Auckland Province showing the close similarity with the Dominion data shown in Fig. 1 (semi-logarithmic base).

increase in cow numbers in the earlier years under review (see Table II), though agreement is good in the years following 1933–34, when cow numbers have been relatively stable. It seems probable that in the rapid expansion of herds in the depression years some degree of " overstocking " occurred—

a process which maximized total production at the expense of production per cow. Also during the period of rapid herd expansion additional young stock would be on hand, and provision of winter feed for these would tend to lower the amount of hay or silage actually fed to milking-cows.

In Taranaki Province the relationship between hay and silage saved and dairy production is not so close as it is for Auckland Province or for the Dominion as a whole. In two seasons since 1929–30 the area cut for hay or silage has failed to forecast correctly the movement of dairy production in the following season. The discrepancies are small and may be due to the use of data for years ending 31st March.

From the high degree of correlation noted above it follows that the area of hay and silage saved in any one season divided by the butterfat produced in the following season should remain approximately constant. This expectation is in fact realized to a surprising degree, and the figure shows little variation between the Dominion as a whole or Auckland or Taranaki Provinces. The data are shown in graphical form in Fig. 3 and are given in detail in Table II.

It is interesting to note that Taranaki saves slightly more hay and silage per one thousand cows than Auckland Province or the Dominion as a whole, and this is associated with above average production per cow. The increase in per-cow production is, however, not sufficient to prevent a slightly higher level of area of hay and silage per 100,000 lb. of butterfat.

In contrast with the above, the area of grassland top-dressed per one hundred cows or per 10,000 lb. butterfat shows wide fluctuations over the period. As between areas, however, the figures show remarkably similar trends. The area top-dressed per one hundred cows or per 10,000 lb. butterfat is at a slightly lower level in Taranaki than in Auckland Province or for the Dominion as a whole. This may be due to the fact that Taranaki is a more exclusively dairying area and little "fat-lamb country" is included in the area top-dressed, or it may be regarded merely as confirmation of the widely-held view that in Auckland Province top-dressing is more essential to continued high production than it is in Taranaki.

In Table IV below are shown correlation coefficients between variations in the area cut for hay and silage and variations in dairy production in the following season, together with similar data in respect of area top-dressed, over the period 1930–43.

TABLE IV.—SHOWING THE CORRELATION BETWEEN FLUCTUATIONS IN THE AREA CUT FOR HAY AND SILAGE AND FLUCTUATIONS IN TOTAL BUTTERFAT SUPPLIED TO DAIRY FACTORIES IN THE FOLLOWING SEASON (YEAR ENDING 31ST MARCH), AND BETWEEN FLUCTUATIONS IN THE AREA TOP-DRESSED AND DAIRY PRODUCTION, OVER THE PERIOD 1930–43

Area.	Hay and Silage and Dairy Production.	Significance.	Area top-dressed and Dairy Production.	Significance.
Dominion	$r = +0 \cdot 77$	SS	$r = +0 \cdot 30$	NS
Auckland Province ..	$r = +0 \cdot 78$	SS	$r = +0 \cdot 50$	NS
Taranaki Province ..	$r = +0 \cdot 51$	S	$r = +0 \cdot 24$	NS
Wellington Province	$r = +0 \cdot 63$	S	..	..

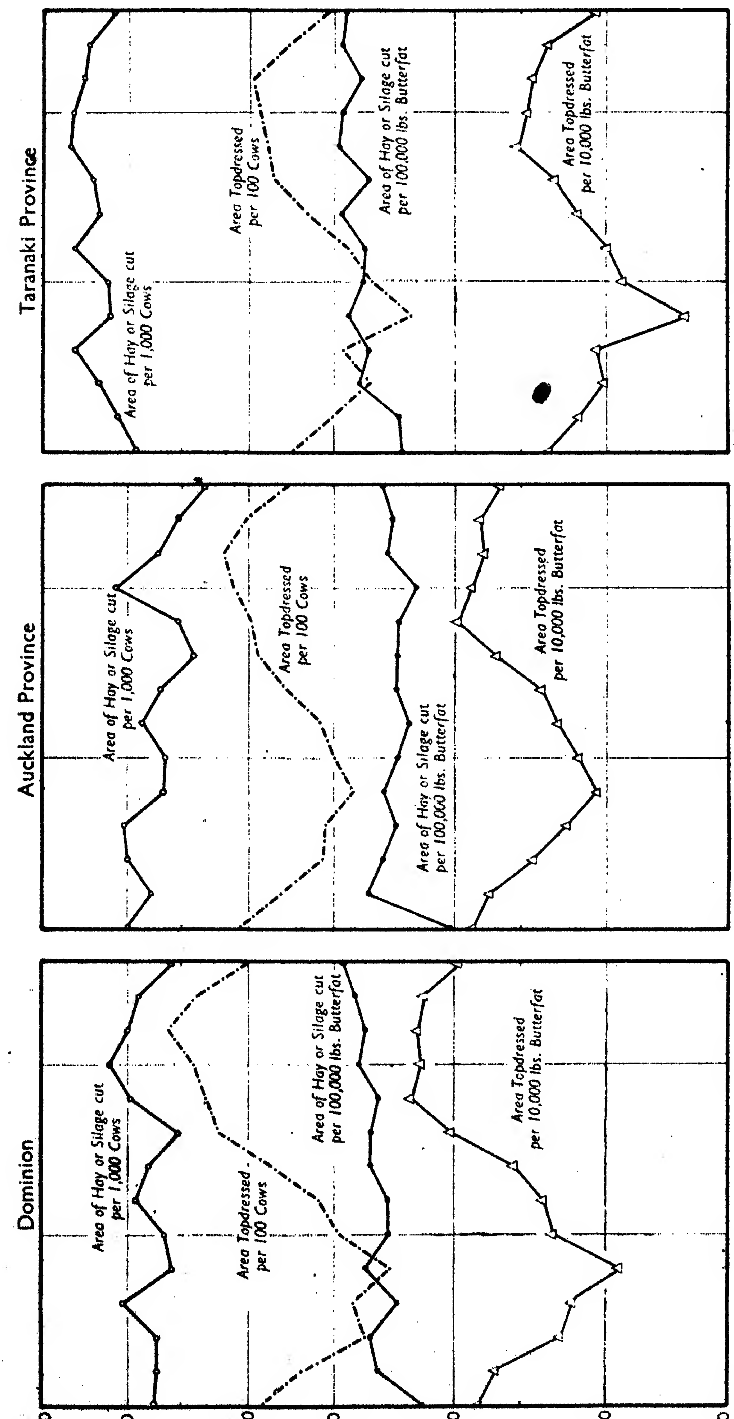


FIG. 3.—Showing for the Dominion and for Auckland and Taranaki Provinces the area of hay or silage cut per one thousand cows, and area cut in the previous season per 100,000 lb. of butterfat produced; also area top-dressed per one hundred cows and per 10,000 lb. butterfat produced. Note the relative stability of area cut for hay or silage per 100,000 lb. butterfat (semi-logarithmic base).

In order to examine the possibility that fluctuations in the area top-dressed might be due to changes in area of sheep pastures top-dressed rather than to changes in area of dairy pastures top-dressed, top-dressing statistics for the

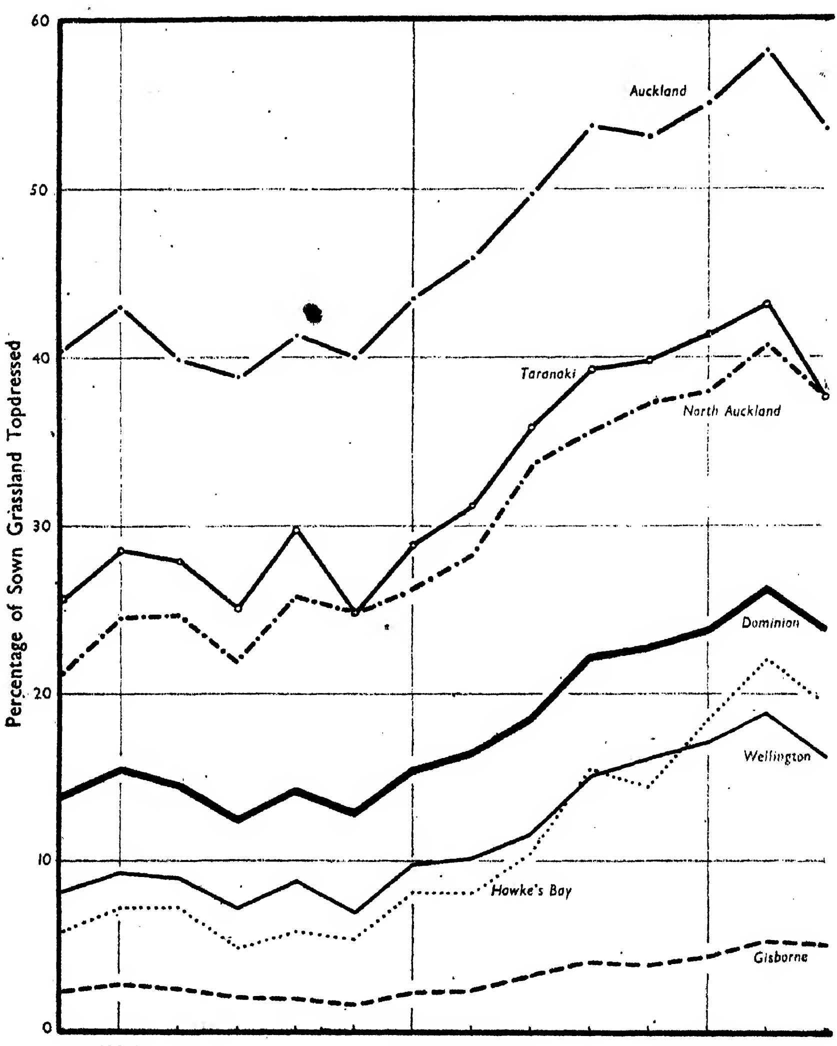


FIG. 4.—Showing for the Dominion as a whole and for the six land districts in the North Island the area of grassland top-dressed with fertilizers or lime, expressed as a percentage of the total sown grassland. The relative movement has been very similar in all districts, irrespective of whether they are predominantly sheep or dairying areas. The percentage of total sown grassland top-dressed, however, varies from 10 per cent. in Gisborne Land District to 58 per cent. in Auckland Land District in 1940–41.

six North Island land districts were brought into line with the Dominion data, using the same methods of reconciliation. The area top-dressed was then expressed as a percentage of the area of sown grass in the land district, the results being shown in detail in Table V and graphically in Fig. 4.

TABLE V.—(*a*) AREA OF GRASSLAND TOP-DRESSED WITH LIME OR FERTILIZERS (THOUSAND ACRES); AND (*b*) PERCENTAGE OF SOWN GRASS TOP-DRESSED IN NORTH ISLAND LAND DISTRICTS

Season.	North Auckland.		Auckland.		Gisborne.		Hawke's Bay.		Taranaki.		Wellington.	
	(*a*)	(*b*)	(*a*)	(*b*)	(*a*)	(*b*)	(*a*)	(*b*)	(*a*)	(*b*)	(*a*)	(*b*)
1928–29..	342·8	21·1	887·0	40·4	33·7	2·1	106·8	5·8	317·6	25·7	291·3	8·2
1929–30..	406·1	24·5	948·0	43·0	42·3	2·6	131·7	7·2	353·7	28·5	329·1	9·3
1930–31..	*415·5*	24·7	*894·9*	39·9	*36·9*	2·4	*133·1*	7·3	*332·8*	27·9	*315·9*	9·0
1931–32..	*371·7*	21·9	*860·1*	38·9	*30·5*	1·9	*887·5*	4·9	*299·7*	25·1	*250·1*	7·2
1932–33..	432·7	25·8	916·1	41·3	29·1	1·8	105·6	5·8	347·2	29·8	311·9	8·9
1933–34..	416·4	24·9	807·2	40·0	22·9	1·5	99·6	5·4	286·9	24·9	244·0	7·0
1934–35..	441·1	26·2	987·7	43·5	35·6	2·2	156·9	8·2	329·8	28·9	344·2	9·8
1935–36..	472·4	28·2	1,060·1	45·9	36·1	2·3	158·8	8·2	356·0	31·2	354·6	10·1
1936–37..	569·1	33·5	1,138·2	49·7	50·9	3·2	205·7	10·5	403·7	35·9	414·1	11·7
1937–38..	615·5	35·5	1,234·4	53·7	65·0	4·1	301·0	15·5	442·0	39·3	523·1	15·0
1938–39..	643·7	37·3	1,256·0	53·1	61·3	3·9	283·5	14·5	447·8	39·8	561·4	16·2
1939–40..	668·2	38·0	1,335·8	55·0	69·8	4·4	353·8	18·5	469·3	41·4	594·7	17·2
1940–41..	723·5	40·7	1,429·3	58·3	83·9	5·3	415·8	22·0	490·0	43·1	652·0	18·9
1941–42..	673·1	37·9	1,312·4	53·5	80·2	5·1	375·0	19·8	431·3	37·6	567·1	16·3
1942–43..	576·5	..	1,128·1	..	54·4	..	281·4	..	366·5	..	403·0	..

The movement has been remarkably similar in all districts, whether these are predominantly sheep or dairy districts. In recent years the area top-dressed in Hawke's Bay has shown a marked increase, and there is little doubt that the peak of area top-dressed in 1940–41 was considerably augmented by areas of sheep pasture top-dressed. It is also interesting to note that in the peak year, 1940–41, over 58 per cent. of the sown grass in Auckland Land District was top-dressed; this figure must closely approach the total of "cultivated" grassland in the area.

Causes of Seasonal Fluctuations

In view of the relationships discussed above, it becomes important to ascertain, if possible, the reasons underlying seasonal fluctuations in the area cut for hay and silage or the area top-dressed. One simple explanation of variations in the area cut for hay and silage is climatic conditions affecting growth during the spring and early summer. While climatic conditions undoubtedly influence yields per acre and to some extent area cut, it would appear that some other factor is also important in the latter case.

It seems probable that conservation of surplus spring growth as hay or silage is generally regarded as an alternative to top-dressing, the choice depending on relative costs in terms of the product, in this case butterfat. In Table VI is shown the cost of dairy-farm labour in terms of the number of pounds of butterfat required to pay cash wages and also the cost of superphosphate in terms of the number of pounds of butterfat required to purchase 1 ton.

The data are shown graphically in Fig. 5, the 1929–30 season being taken as base 100. Figure 5 makes it clear that, as wages fell during the depression, increasing quantities of hay and silage were saved, while the area top-dressed contracted somewhat in response to the rising cost of superphosphate, though a temporary fall in price in 1932–33 was responsible for an immediate increase in the area top-dressed. Fluctuations in the cost of labour show a fairly close inverse relationship with area saved for hay and silage, though the agreement is not so close ($r = -0{\cdot}23$) as in the case of area top-dressed, which showed a steady rise as the price of superphosphate fell in terms of butterfat ($r = -0{\cdot}76$). It may be objected that hired labour accounts for only some 20 per cent. of the male labour force employed in dairying and that changes in wage level are not likely to have the effect ascribed to them.

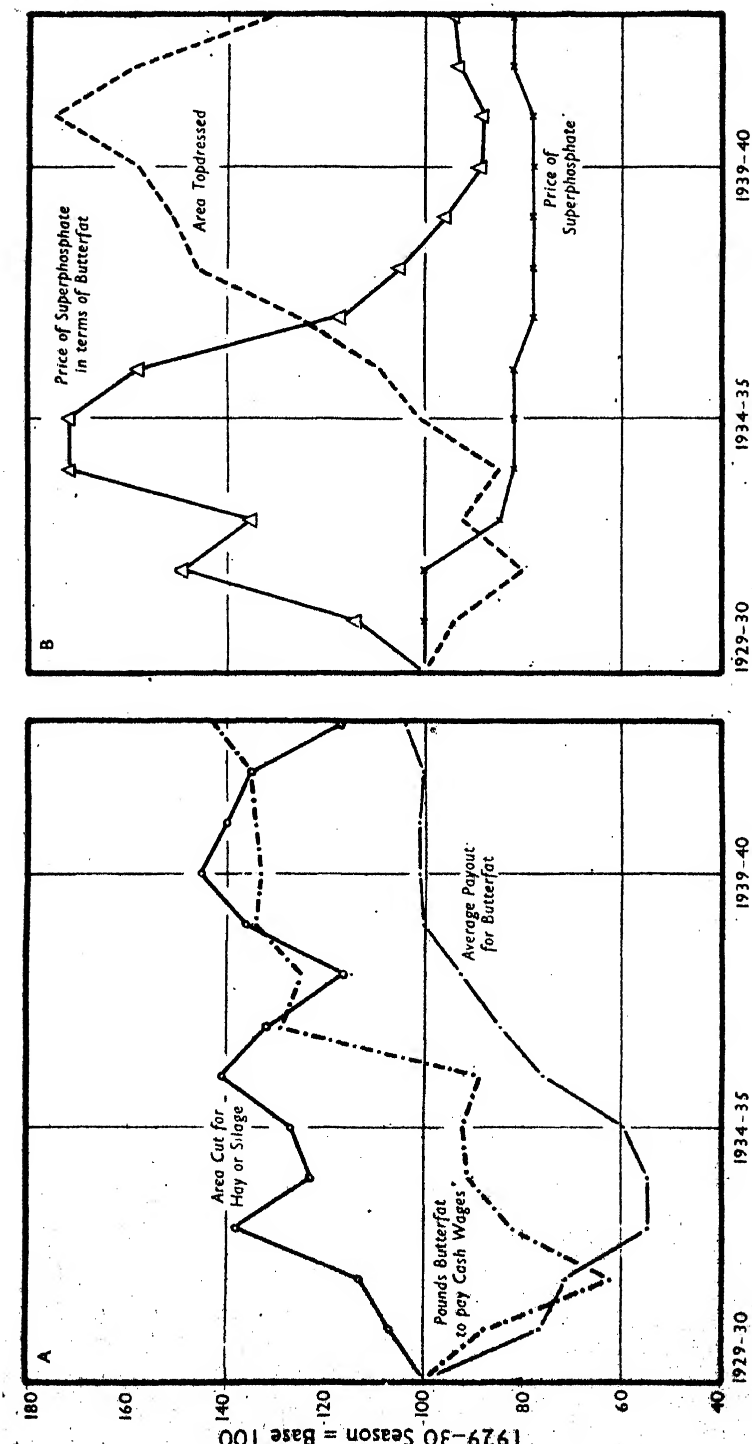


FIG. 5.

(*a*) Showing the relationship between the area cut for hay or silage, the number of pounds of butterfat required to pay cash wages, and the average payout per pound of butterfat supplied to a butter-factory.

(*b*) Showing the relationship between area top-dressed and the price of superphosphate in terms of butterfat. The price of superphosphate per ton is also shown.

Hired labour is, however, important on the larger farms; 3 per cent. of suppliers with herds of over one hundred cows produce as much butterfat as the 52 per cent. with herds below twenty-five cows. It must be also remembered that wage levels are indicative of the availability of labour as well as its cost.

TABLE VI.—FACTORS AFFECTING THE AREA CUT FOR HAY OR SILAGE AND THE AREA OF GRASSLAND TOP-DRESSED ANNUALLY IN THE DOMINION, 1928–29 TO 1942–43

Season.	Average Payout per Pound of Butterfat (Butter-factory) (Pence).	Cash Wages of Adult Male Dairy-farm Workers.		Price of Superphosphate* per Ton, f.o.r. Westfield, 1st March.	
		Per Week.	In Terms of Butterfat (Pounds).	In Cash.	In Terms of Butterfat (Pounds).
		s. d.		£ s. d.	
1928–29 ..	18·25	39 0	25·6	4 17 6	68·4
1929–30 ..	16·00	39 0	29·2	4 17 6	64·0
1930–31 ..	12·25	26 3	25·7	4 17 6	73·1
1931–32 ..	11·45	17 6	18·3	4 17 6	95·5
1932–33 ..	8·75	17 6	24·0	4 2 6	86·5
1933–34 ..	8·75	19 5	26·6	4 0 0	110·0
1934–35 ..	9·50	21 3	26·8	4 0 0	110·0
1935–36 ..	12·12	26 3	26·0	4 0 0	101·0
1936–37 ..	13·56	42 6	37·6	3 16 0	75·0
1937–38 ..	14·81	45 0	36·5	3 16 0	67·4
1938–39 ..	16·09	52 6	39·1	3 16 0	61·5
1939–40 ..	16·18	52 6	38·9	3 16 0	56·7
1940–41 ..	16·11	52 6	39·1	3 16 0	56·4
1941–42 ..	16·02	52 6	39·3	4 0 0	59·5
1942–43 ..	16·58	57 6	41·6	4 0 0	60·0

* Statistics of the area top-dressed are collected at 31st January in each year and refer to the area top-dressed in the twelve months preceding that date. Since most top-dressing of pastures is carried out in the autumn months, this means that the top-dressing shown as applied in, say, the 1929–30 season was actually largely applied in the latter part of the 1928–29 season, though its main effect on production would occur in the 1929–30 season. The area top-dressed would, however, be determined by conditions ruling in the autumn of 1929, and the figures shown opposite the 1929–30 season refer to the price of superphosphate at 1st March, 1929, and, in terms of butterfat, this price divided by the average payout for the 1928–29 season, not the 1929–30 season.

There is little doubt that the issues determining the area top-dressed or the area cut for hay or silage are more complex than the simple explanation given above, but relative costs and the availability of labour are almost certainly the major determining factors.

DISCUSSION

The relationships discussed above indicate that approximately 60 per cent. of the seasonal variance in dairy production for the Dominion as a whole is associated with changes in the area cut for hay or silage in the previous season—*i.e.*, with the level of pre-lactation feeding—and suggest that top-dressing is not a substitute for adequate winter feeding. This in no way minimizes the increased production to be obtained by the top-dressing of pastures, but it does emphasize the necessity for fully utilizing the increased feed produced, by conservation of the spring and summer surplus as hay or silage, and the necessity for adequate winter feeding if dairy cows are to profit during the milking season by the higher yield from adequately fertilized pastures.

It also raises a doubt as to the wisdom of the policy, common in some districts, of wintering the dairy herd on a hill "run-off." In many cases such areas receive no top-dressing and provide a bare existence, often in competition with sheep or run cattle. Such conditions provide little opportunity for a cow to replenish her store of minerals or to build up reserves for a heavy producing season. No matter how lush the spelled pastures to which such animals return in the spring, production may easily be disappointing.

The relationships outlined above present no novel features. They do, however, serve to illustrate in concrete form the practical importance of what has long been regarded as axiomatic—viz., the importance of adequate winter feeding.

REFERENCES

(1) HAMILTON, W. M.: *N.Z. Jour. Sci. & Tech.*, *24*, 23A.
(2) ——— *Proceedings 2nd Annual Conf. N.Z. Society Animal Production.*

ROOT-DEVELOPMENT IN SOME COMMON NEW ZEALAND PASTURE PLANTS

III. RYE-GRASS, COCKSFOOT, AND WHITE CLOVER

THE REGENERATIVE POWER OF ROOTS AND ITS RELATIONSHIP TO GRASSLAND HARROWING

By W. A. JACQUES, Massey Agricultural College, New Zealand

(Continued from Vol. 25, No. 3 (A Sect.), October, 1943, p. 117)

Summary

The effect of root severance on the root behaviour of several grasses is discussed. It is considered that the severance of a proportion of the roots such as could occur as a result of harrowing offers no advantage to the plant but actually reduces the number of deeply-penetrating roots that are available for food or water supply during summer. Different types of laterals develop in early spring from those formed in late spring or early summer.

INTRODUCTION

IN New Zealand there has been much controversy regarding the efficacy and the advisability of the use of heavy penetrating harrows to counter the pugging effect of stock grazing on the permanent pasture in winter. A dozen years ago there was a general feeling that if a permanent sward were heavily harrowed with an implement with cutting or penetrating tines until little could be seen of the grass, that improvement would be effected in the productive capacity. Since that time there has arisen a doubt as to the efficacy of this treatment, and much lighter harrowings are now given. There is still a feeling, despite the lack of experimental evidence, that sod-bound, unproductive swards consisting of such plants as paspalum (*Paspalum dilatatum*) and brown-top (*Agrostis tenuis*) as the dominant grass species can be made more productive by tearing or penetrating harrows. Similarly, pastures that have had the surface badly poached by winter grazing may

also respond in some degree. Some machinery vendors have put forward claims that root severance of pasture plants before the commencement of spring growth is a decided advantage to the plant in that it engenders the formation of new root-growth. There appears to be no sound basis for this statement. Experiments at Marton Experimental Area(1) have shown that on high-producing, well-grazed dominant perennial rye-grass swards harrowed in autumn and winter over a number of years, no significant difference in production was recorded as against the untreated ones. The figures given are as follows:—

TABLE I.—DRY MATTER, IN POUNDS PER ACRE, AND RELATIVE YIELDS (NO HARROWING = 100)

(Based on dry matter for the period 14th September, 1934, to 18th July, 1939)

Treatment.	Dry Matter (Pounds per Acre).	Relative Yields.
1. No harrowing	48,014	100
2. Autumn harrowing (April, May)	47,669	99·3
3. Autumn and winter harrowing (April, May, and July) ..	47,119	98·1
4. Winter harrowing (July)	46,595	97·0

Each area received two strokes with the harrows, the second being at right angles to the first. Grazing was done with sheep.

The general conclusions were that, over a five-year period, no improvement was noted either in seasonal production or in the total yields of herbage when a double harrowing was given to a depth of 1 in. to 1½ in.

It is possible that different species react to what amounts to root-pruning in different ways, but as the most important and widely distributed grass species on lowland dairy pastures is perennial rye-grass (*Lolium perenne*) this species has been taken as forming a basis for a trial on the regenerative capacity of grass roots when severed at intervals from May to August. In addition to three perennial rye-grass strains, Italian rye-grass (*L. multiflorum*), Western Wolths (*L. westerwoldicum*), and cocksfoot (*Dactylis glomerata*) have also been tested with the object of comparing their responses under similar treatment.

The results for Western Wolths have not been included in one trial as most of the plants died before its completion.

MATERIALS AND METHOD

The trial was divided into two parts, the first had as its object the observation of root-responses to a vertical cut on two sides of plants that were more than twelve months old, the second was to determine the response to horizontal root severance at 2 in. below the surface with plants less than twelve months old. The latter would have its application rather in the effect of root-cutting insects (such as *Odontria* in this country) and not as a factor in harrowing.

Side Cut

One strain of certified perennial rye-grass (BA 6426), two uncertified perennial lines—BA 6378 (an average type 3) and BA 6374 (a poor type 5)—and a good Italian rye-grass (Bb 283) were planted singly in rows in autumn

and allowed to develop for thirteen months before the cutting treatment was commenced.* The cut was made with a sharp spade on two sides of the periphery of the plants. Different plants were cut at fortnightly intervals between 15th May, 1940, and 7th August, 1940, and were raised for examination approximately three months later. Counts that were made between 9th August, 1940, and 11th October, 1940, were not complete, but indicated little change from the figures obtained on the earlier count so have not been included. One hundred severed roots were examined on each plant, and Table II gives the results of the counts on the different dates. Most of the roots that were examined were 1 in. or more between the proximal end and the place of severance. Most of those that were cut shorter than this, unless they had very recently been initiated, failed to exhibit any regenerative powers.

TABLE II.—EFFECT OF ROOT-PRUNING (SIDE CUT)

Description		Cut followed by Lateral Root-growth.							Cut followed by no Lateral Root-growth.				
Date of Cutting.	Date of Sampling.	Distance of Cut from the Plant.				Average Length of Lateral Growth (in Inches).	Length of Longest Lateral (in Inches).	Percentage of Roots.	Distance of Cut from the Plant.				Percentage of Roots.
		<½"	½"	1"	>1"				<½"	½"	1"	>1"	
		Plant BA *6426 (Selection)*											
		%	%	%	%				%	%	%	%	
15/5/40	9/8/40	1	6	12	43	1·30	7	62	..	3	10	26	38
10/7/40	11/10/40	1	4	5	58	1·19	6	68	1	1	..	30	32
24/7/40	18/10/40	..	3	9	53	0·86	4	65	..	4	4	27	35
7/8/40	11/11/40	1	..	1	47	1·00	6	49	..	1	4	46	51
		Plant BA *6378 (Average Type 3)*											
15/5/40	9/8/40	3	..	4	43	0·89	4	50	4	10	16	20	50
10/7/40	11/10/40	2	3	5	46	1·82	6·5	56	1	4	15	24	44
24/7/40	18/10/40	..	3	5	42	0·65	3	50	..	4	6	40	50
7/8/40	11/11/40	..	2	3	48	1·28	5	53	..	..	7	40	47
		Plant BA *6374 (Poor Type 5)*											
15/5/40	9/8/40	8	4	11	7	0·20	3	30	2	15	23	30	70
10/7/40	11/10/40	1	2	5	24	1·00	3	33	3	5	17	42	67
24/7/40	18/10/40	..	1	7	25	0·76	3	33	5	7	13	42	67
7/8/40	11/11/40	9	7	20	16	1·44	4·5	52	..	4	3	41	48
		Plant Bb *283 (Good Italian Rye)*											
15/5/40	9/8/40	4	9	4	35	1·63	5	52	1	5	15	27	48
10/7/40	11/10/40	..	3	6	31	0·93	4	40	..	5	18	42	60
24/7/40	18/10/40	1	3	6	32	0·57	2	44	2	6	10	38	56
7/8/40	11/11/40	1	2	16	50	0·80	5	69	..	5	9	17	31

Discussion of Results of Side Cutting.—In the certified perennial rye-grass (BA 6426) there was a relatively high proportion of replacement of severed roots by laterals and these laterals reached an average length of between 1 in. and 1·3 in., with 7 in. as the longest. The number of laterals that developed above the severed portion was not ascertained in this trial as it was not always possible to distinguish between normal and induced lateral growth.

* Thanks are due to the Director of the Grasslands Division of the Plant Research Bureau for supplying the lines of seed from plants of known performance and uniformity.

In the perennial rye-grass type 3 (BA 6378) a fairly uniform figure for the number of roots that regenerated was maintained throughout, but the capacity of the roots to send out laterals after severance was not so great as in the selection (BA 6426), and the longest lateral formed was 6·5 in. In the type 5 rye-grass (BA 6374) the regenerative capacity was the lowest of any tried and, with the exception of the last count, only one-third of the roots that were cut sent out laterals. This is in great contrast to the selection (BA 6426), which showed almost double that number. The final count on 11th November, 1940, showed an increase in the number that continued growth, and this was due solely to the greater number of new roots that had developed around the periphery of the plant to replace the centre ones that had died during the previous summer. It indicates a more transient root system, where the older roots are more vigorously replaced in spring than was found in the longer-lived perennial form (BA 6426). Italian rye-grass (Bb 283) gave a somewhat better figure for replacement than type 5 perennial, but here also the new roots that had developed around the periphery at the end of July and early August led to an apparent increase in the regenerative capacity of the roots. The progressive decrease in vigour of regeneration during the period of the first three counts is shown by a steady decrease in both the average and the greatest length of the laterals that developed.

It would seem, therefore, that there is a greater regenerative capacity in newly-formed roots, and that older roots become progressively less responsive to severance.

Counts made on perennial rye-grass pasture plots in an adjoining area show that from 15 per cent. to 30 per cent. of the total main roots are severed when parallel cuts 2 in. apart and 2 in. deep are made.

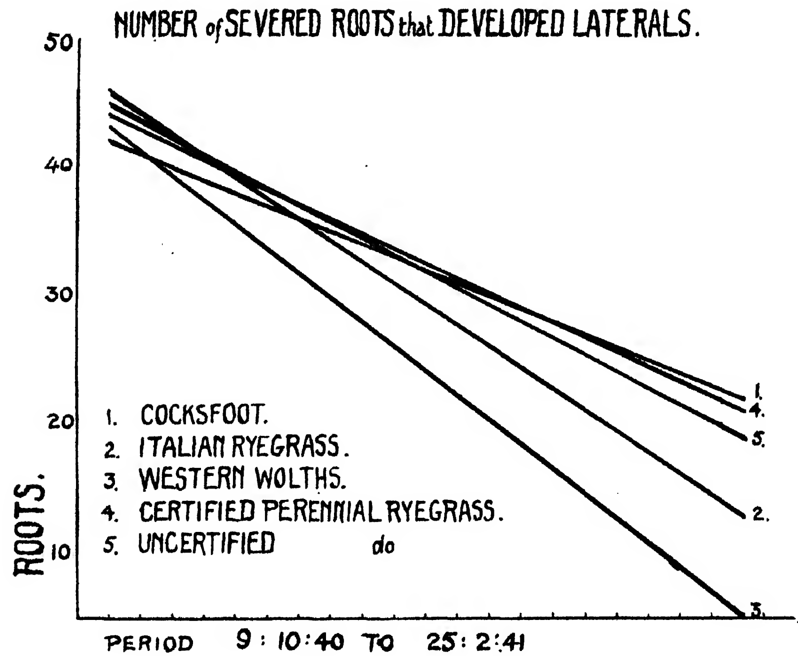
Under-cut Series

The grasses tested in this trial were certified perennial rye-grass; uncertified perennial rye-grass; Italian rye-grass; Western Wolths; certified mother cocksfoot. White clover was also treated in the same way.

Plants were grown as single plants from clones. Weekly cutting of the roots was commenced on 1st July, 1940, and continued until 18th November, 1940. The plants were raised approximately three months after root-severance. The roots were cut *in situ* by passing a sharp, thin blade beneath each plant at approximately 2 in. below the surface with as little disturbance of the soil as possible. The treatment was more severe than the side cut, and most of the roots were severed. Fifty roots from each plant were examined at weekly intervals between 9th October, 1940 (when those plants whose roots were cut on 1st July were examined), and 25th February, 1941 (when the experiment terminated).

Discussion of Results.—Figure 1 shows the trend in the different plants as regards their ability to develop lateral root-growth after the main roots had been severed. It will be noted that, as the roots became older, they showed a sharp decline in the number that responded to severance. Cocksfoot and the perennial rye-grasses showed the best response, while the annual and short-lived forms of rye-grass showed the least.

The average length of the laterals that did develop in consequence of cutting also declined as the roots increased in age before being severed (Fig. 1).



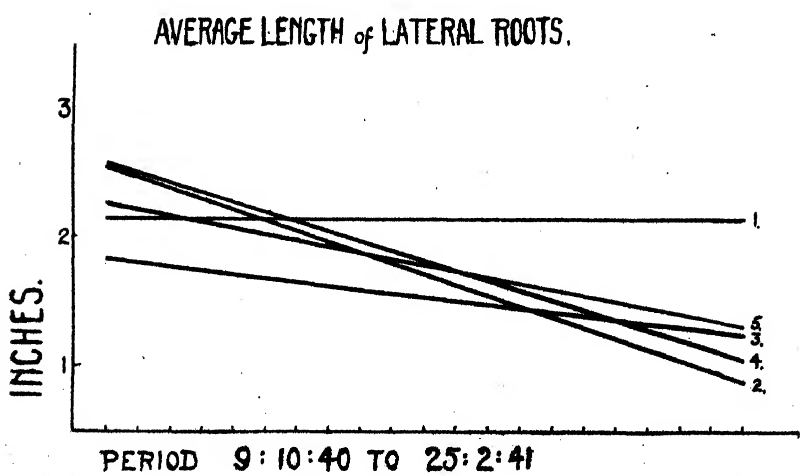


FIG. 1.

Cocksfoot was outstanding in that it was able to maintain both the longest average length of laterals and the highest number of severed roots that developed laterals.

Figures 2 and 3 show the type of growth that followed upon severance of the roots in the three months between cutting and lifting. It is interesting to note that the thinner white roots sent out more laterals, and generally these penetrated to a greater depth in the soil than did the thicker white roots, except in cocksfoot, where the trend was reversed.

Figures 2 and 3 demonstrate clearly the different type of root-growth that follows severance in early and late spring and which is progressive into summer. Figure 2 shows roots of uncertified perennial rye-grass from the " under-cut " series. The roots were severed at the points marked with arrows.

FIG. 2.—Uncertified perennial rye-grass. Severed roots from an " under-cut " plant. Lateral root-growth is vigorous from an area immediately above the cut and extends well below it. Arrows indicate point of severance. (Roots cut, 1/7/40; plant raised, 9/10/40.)

On the left of Fig. 2 is a " looping " of the root and the formation of laterals as a consequence of some disturbing feature of growth. Similarly in the next root, the main root-tip has been destroyed, and immediately behind the damaged portion arise several laterals. The two roots on the right were severed on 1st July, 1940, and examined on 8th October, 1940. They show lateral root-growth, which has replaced the severed main roots and are exhibiting a vigorous downward growth.

The type of lateral growth is very different in Fig. 3, which shows roots cut more than three months before they were raised on 2nd March, 1941. Here the lateral growth is characteristically gnarled, much branched but short, with little vigour or tendency to penetrate deeply. This transition from the vigorous growth of early spring to the much less vigorous response

in the late spring or early summer is also indicated by Fig. 1, where there is shown a decline in the average length of the lateral growth. This decline was less evident in the side-cut series, where the cutting commenced and ended at an earlier period than in the under-cut series, and also where the severed roots were younger.

White Clover

The effect of root-severance on white clover was to cause from four to twelve laterals to form above the cut (Fig. 4). These were thinner than the original tap-root, but penetration was only slightly affected. The behaviour of the clover-root differed considerably from that of the grass-roots in that replacement by the adventitious root-system was slower and deterioration of the roots (which is a marked feature of the grasses from July onwards) was less apparent in the clover.

FIG. 3.—Certified perennial rye-grass. Severed roots from an "under-cut" plant. Lateral root-growth is short and gnarled, and on only one root did the lateral growth extend below the point of severance. Arrows indicate the point of severance. (Roots severed, 18/11/40; plant raised, 2/3/41.)

GENERAL DISCUSSION

It can be determined from the above data that from 15 per cent. to 30 per cent. of the plant-roots can be severed by harrowing with cutting tines 2 in. apart and 2 in. deep. Of these severed roots a decreasing proportion recommence growth as the spring passes into summer. In certified perennial rye-grass almost 40 per cent. of side-cut roots failed to make further growth. This means that between 6 per cent. and 12 per cent. of the total root numbers are destroyed by root-severance. In the two uncertified rye-grasses the figures are more impressive and range between 7·2 per cent. and 14·4 per cent. and 9·4 per cent. and 19 per cent. for types 3 and 5 respectively. In many cases

the number of newly-formed laterals exceeds the number of main roots that have been lost by cutting. The effect of this may be a temporary improvement in yield, for the new roots are thickly clothed with root-hairs which are developed in a region of the soil that is generally well supplied with plant-food. The length of the lateral root-growth following severance, however, is less than is desirable from the point of view of root-penetration. In effect it is causing the replacement of part of the deeper-penetrating root-system

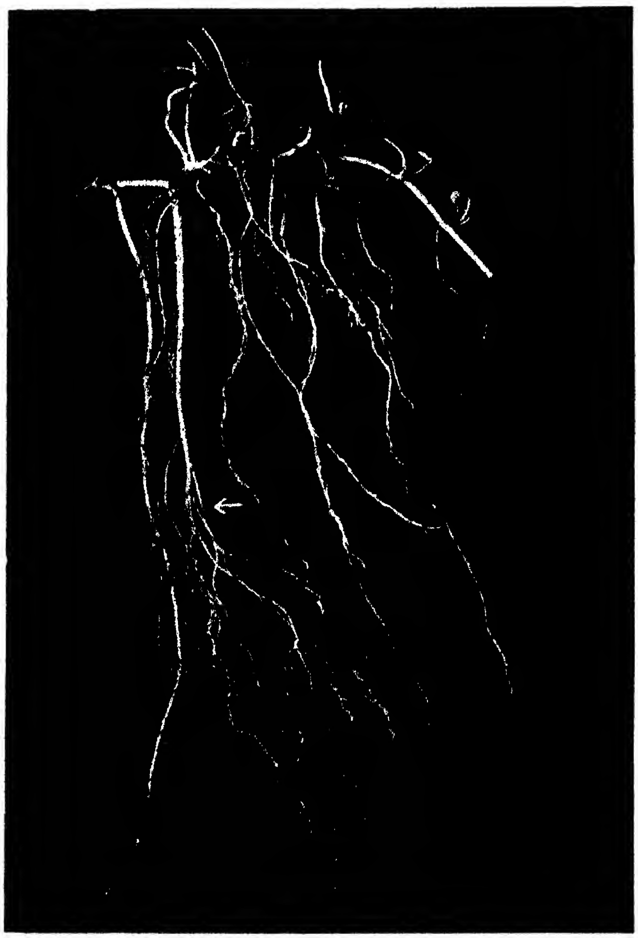


FIG. 4.—White clover. Severed tap-root from an "under-cut" plant. Lateral root-growth is vigorous. Six strong lateral roots are vigorously replacing the severed tap-root. At the same time adventitious roots are developing. (Roots severed, 18/11/40; plant raised, 3/3/41.)

with a more superficial though temporarily a more vigorously absorbing one. It is possible, therefore, that while ample soil-moisture remains, there may be as a consequence an increase in yield during spring. But the production of spring growth is not a problem that is facing the farmer. It is the summer yield that is important, and here the effect of root-severance is likely to be detrimental to yield. As moisture becomes less abundant in the upper

soil layers with the approach of summer, the trend is for roots to penetrate into the deeper and moister subsoil. The severed roots, especially those severed late in the trials, have shown little tendency to do this, so that they become useless as absorbing agents in the drier season. Thus when a supply of food and moisture is most needed it is mainly the unsevered roots that supply it.

Furthermore, the roots that give the greatest response to root-severance are relatively young, and these are the ones that are in the process of growing down into the subsoil. The roots that have already penetrated deeply are on the whole not in a state to regenerate near the surface and have mostly lost their cortical tissue. When a root has reached the stage when the cortex sloughs from around the stele there is little, if any, response to root-severance. Although some roots have been observed which have no cortical tissue above the point of severance and have yet shown some lateral growth it may be that sloughing took place subsequent to the initiation of lateral root-growth.

Though no herbage weights were taken in this trial, it is clear from a root-development viewpoint that no advantage is to be looked for as a result of root-pruning. The effect is to transfer the absorption region of some portion of the root system from the deeper soil layers to a region nearer the surface. While this may be satisfactory in a soil that does not dry out and where the water-table is never far from the surface, it undoubtedly affects the summer production on soils where dry periods are experienced. It seems possible that this is the major factor operating as far as the roots are concerned. Under normal conditions grass-roots can readily be replaced at short notice if the plant is in need of them. The fact that the lateral growth following upon severance of the main roots can supply abundant food from near the surface forms no incentive for the plant to replace the severed deep roots with more deep roots. From this viewpoint, therefore, the claim that root-pruning due to penetrating harrows is beneficial cannot be supported.

A point of less importance is the actual loss of food material from those roots that were cut. The bulk of the roots that sent out laterals were young roots and contained some food stored in the cortex. Judging by the behaviour of the cortex, this reserve of food is called upon mainly when the plant is preparing to form seed-heads. This loss of food *per se* is therefore of little consequence and is still available to the plant at some future time.

There is some severance of the roots that grow outwards or fanwise from the plant, and these are likely to be more affected by harrowing than are those roots that grow more or less directly downwards. Some of these penetrate deeply, others do not. Cocksfoot and *Paspalum dilatatum* would be more affected in this connection than perennial rye-grass.

The roots that are likely to suffer also are the finely-branched, short, superficial roots which usually penetrate only a few inches into the ground. These roots are different in form from the white roots, and their function appears to be to take up a supply of the minerals from the surface layers immediately round the crown of the plant. They are not able to function in very dry soil.

The fact that the new lateral growth which develops consequent upon cutting is well supplied with root-hairs to a large extent neutralizes the loss of some main roots and permits absorption from near the surface until such time as the ground becomes too dry for them to function or they lose their cortex and, with it, the root-hairs.

In the undercut series the short, much-branched, surface-feeding roots were hardly affected and those that normally penetrate deeply only were severed. The latter behaved similarly to those in the side-cut series. In all cases the peripheral roots made more lateral root-growth than the older ones that were produced from the more centrally placed tillers. The fact that most of the older roots had shed their cortex near the surface of the ground does not imply that they had ceased to function as absorbing organs; the distal ends could still be elongating and actively absorbing, though there would be little absorption in the top foot of soil.

There is a steady decline in the ability of the grass-roots to respond to severance as they become older, and it is very questionable whether roots that have shed their cortical tissue do respond at all. The degree of response was measured by their ability to develop vigorous and numerous laterals to replace the severed main root and also by the average length attained by them. Cocksfoot and certified perennial rye-grass showed the best response in the number of severed roots that developed laterals, while cocksfoot was outstanding in the length of roots that so developed.

White clover seemed to be little affected by root-severance where the function of the severed tap-root was taken over by one or more of the lateral roots.

REFERENCE

(1) ELLIOTT, A. G., and LYNCH, P. B. (1940): *N.Z. Jour. Agri.*, *60*, 279.

MARROW-STEM KALE

FURTHER INVESTIGATIONS

By R. A. CALDER, Agronomy Division, Department of Scientific and Industrial Research

Summary

Two distinct strains of marrow-stem kale (chou moellier) now known respectively as "giant" and "medium-stemmed" and a strain of thousand-headed kale have been developed at the Agronomy Division. These were compared in a yield and grazing trial, and as all were considered to be of value for forage purposes, seed-supplies of each have been built up and are to be distributed by the Department of Agriculture.

INTRODUCTION

A RATHER significant feature in connection with the production of fodder crops in New Zealand during recent years has been the gradual increase in the acreage devoted to marrow-stem kale, commonly known in this country as chou moellier. Throughout the same period the area sown with rape has remained relatively constant, whereas that sown with turnips has exhibited a decided decrease. A record of the changes which have occurred over the past ten years may be observed in Table I, in considering which due allowance must be made for the modification in the system of recording introduced in 1941–42.

TABLE I.—ACREAGES SOWN WITH SOME FORAGE CROPS, 1933–34 TO 1942–43(1)

(Areas in thousands of acres)

Crop.	1933–34.	1934–35.	1935–36.	1936–37.	1937–38.	1938–39.	1939–40.	1940–41.
Chou moellier ..	9·1	8·4	11·7	10·1	11·4	12·7	14·7	19·0
Rape and/or kale ..	188·3	180·5	191·6	195·7	196·4	173·1	189·8	197·9
Turnips	414·9	386·7	381·9	371·5	373·5	332·6	345·9	341·4
Turnips and rape ..	63·7	62·8	59·9	59·9	59·1	53·2	58·9	62·3

Crop.	1941–42.	1942–43.
Kale (including chou moellier)..	63·7	64·4
Rape	163·8	160·8
Turnips .. .. / Swedes	336·9	327·0
Turnips and rape	39·8	38·1

This would seem to indicate that marrow-stem kale is tending to replace, in some degree at least, a portion of the turnip crop. The reason for such a change over could no doubt be accounted for by the fact that, in many localities, great difficulty is experienced in obtaining satisfactory crops of turnips due to the ravages either of aphis, of diamond-back moth, of club-root, or of dry rot. Marrow-stem kale is not so susceptible to these pests, and as it constitutes an excellent late autumn or early winter forage, is apparently being grown to some extent in preference to the root crop. That such a replacement is occurring is supported by observations, and it is possible that it will become even more extensive in the future.

Until comparatively recently the seed-supplies for sowing the kale acreages were obtained almost entirely from overseas, but arrangements have been made by the Department of Agriculture which provide for the production locally, under official supervision, of all seed requirements. At the Agronomy Division efforts have been directed towards the development of reselected types which now form the nucleus material for the seed-production scheme.

In a previous article(2) the crop and plant characteristics of marrow-stem kale were discussed and a description given of the methods being used to develop selected strains. Three distinct forms had been isolated, and these were to be subjected to further selection and to more comprehensive field trials. The present article discusses the results obtained from a yield and grazing trial of two selected types of marrow-stem kale and one of thousand-headed kale; the third marrow-stem kale strain was discarded.

MATERIAL AND METHODS

The material under trial consisted of the following selected types (see Fig. 1):—

(i) A tall form with a smooth, well-developed stem and with a rather low proportion of leaf to stem, now known as giant chou moellier:

(ii) A form of medium height with a relatively coarse stem but with a greater proportion of leaf to stem than the tall type, now known as medium-stemmed chou moellier:

(iii) A selected form of thousand-headed kale.

These three types were sown in plots each consisting of five rows 45 ft. long and 2 ft. 6 in. apart, each being replicated eight times. The plots were drilled with a Planet Junior on 25th October, 1939, and the first results were recorded on 9th February, 1940. From two of the replicates of each type two subplots four rows by 6 ft. in extent were cut and weighed and later the results averaged to give green-weight yields per plot: samples were also taken for air-dry weight determinations, for leaf-stem analysis, and for stem fractionation. The two replicates were then fenced off and six ewes were turned on and allowed to graze for four days, after which further subplots of a similar dimension to the former were cut and weighed and further samples taken for leaf-stem analysis. From the data thus obtained it was possible to calculate the amount of green forage and the proportions of leaf and stem which had been consumed off each type in four days. Finally the sheep were again admitted to the plots and allowed to complete grazing, after which a third series of subplots was cut and weighed; all the leaf and varying proportions of the stem had been eaten and it was possible to determine not only the total amount of forage, but also the proportions of stem which had been consumed off each type.

FIG. 1.—(*a*) Giant chou moellier; (*b*) medium-stemmed chou moellier; (*c*) thousand-headed kale.

Similar records were obtained from the remaining replicates in March, April, May, and June; in May and June, however, only a single series of plots was investigated at each cutting period, and for these two months the results have been averaged.

No statistical examination was undertaken, and this should be borne in mind when the results are considered.

EXPERIMENTAL RESULTS

The results obtained are discussed under the following headings:—

(*a*) Green-weight yields:
(*b*) Dry-matter determinations:
(*c*) Leaf to stem ratios:
(*d*) Stem fractionation:
(*e*) Grazing:
(*f*) Chemical analyses and nutritive value.

No chemical analyses of the material from the trial were undertaken. Woodman, Evans, and Eden(3), however, in 1934 made a complete study at Cambridge of the composition and nutritive value of marrow-stem kale and thousand-headed kale, and the results of the Lincoln trial are considered in relation to their findings.

(a) *Green-weight Yields*

In marrow-stem kale practically the whole plant is consumable, and therefore in any determination of yield both the leaf and the stem have to be taken into consideration. In the trial under review the plants from the subplots were cut at ground-level for weighing for total production, and the results obtained are presented in Table II.

TABLE II.—TOTAL YIELDS OF GREEN MATTER IN POUNDS PER PLOT AND AS PERCENTAGES FROM THE THREE TYPES AT DIFFERENT PERIODS

Type of Kale.	9/2/40.		7/3/40.		16/4/40.	
	Lb./Plot.	Tall = 100.	Lb./Plot.	Tall = 100.	Lb./Plot.	Tall = 100.
Tall marrow-stem ..	28·0	100	31·4	100	45·2	100
Medium marrow-stem	23·7	84·6	27·9	88·8	35·8	79·2
Thousand-headed ..	21·6	77·1	21·4	68·2	33·1	73·2

Type of Kale.	13/5/40–11/6/40.		Average over Four Periods.		
	Lb./Plot.	Tall = 100.	Lb./Plot.	Tons/Acre.	Tall = 100.
Tall marrow-stem ..	35·6	100	35·0	11·6	100
Medium marrow-stem ..	26·3	73·8	28·4	9·2	81·1
Thousand-headed ..	25·8	72·5	25·5	8·2	72·8

Comments on Table II.—(i) Due to a dry period in the late summer and early autumn, growth was not prolific and the crop grew to a height of only 2 ft. 3 in. to 2 ft. 6 in.; green-weight yields, therefore, were relatively low.

(ii) In all types there was a gradual increase in productivity until the third period, after which decreases were recorded.

(iii) At all periods the tall marrow-stem kale type gave the heaviest yield, the medium marrow-stem kale type somewhat less, and the thousand-headed kale the poorest.

(b) *Dry-matter Determinations*

When the plots were cut for green-weight yields, samples of the leaf and stem were taken and air dried for dry-matter determinations, all references to which, unless otherwise stated, are on an air-dried basis. Dry-matter percentages of the two separates were obtained, and from these were calculated the dry-matter percentage of the whole plant. The results, which were higher than those recorded by Woodman, Evans, and Eden, who give absolute dry-matter figures, are presented in Table III.

TABLE III.—THE AVERAGE GREEN-WEIGHT YIELDS IN POUNDS PER PLOT, AVERAGE DRY-MATTER PERCENTAGE, AVERAGE DRY-MATTER YIELD IN POUNDS PER PLOT, AND CALCULATED DRY-MATTER YIELD IN TONS PER ACRE FROM THE THREE TYPES OVER THE FOUR PERIODS

Type of Kale.	Average Green-weight Yield (Pounds per Plot).	Average Dry Matter. (Percentage).	Average Dry-matter Yield (Pounds per Plot).	Average Dry-matter Yield (Tons/Acre).
Tall marrow-stem	35·0	19·7	6·9	2·2
Medium marrow-stem ..	28·4	20·4	5·8	1·9
Thousand-headed	25·5	22·4	5·7	1·8

Comments on Table III.—Thousand-headed kale gave the highest dry-matter percentage and the lowest dry-matter yield, whereas the tall marrow-stem kale type gave the lowest dry-matter percentage and the highest dry-matter yield.

The differences recorded between marrow-stem kale and thousand-headed kale are of a similar order to those obtained by Woodman, Evans, and Eden, who found that the average dry-matter content (on an absolute basis) of marrow-stem kale during late autumn was 13·3 per cent. and of thousand-headed kale 15·8 per cent., but stated that this advantage of thousand-headed kale was offset by its lower yields in terms of green matter.

(c) *Leaf to Stem Ratios*

At each period, immediately the plots were cut and weighed for total green-weight yield, twenty-five representative plants were taken and the leaves stripped from the stems. The two separates were then weighed and the percentage of leaf to stem calculated. The results obtained are shown in Table IV.

TABLE IV.—PERCENTAGES OF LEAF AND STEM, ON A GREEN-WEIGHT BASIS, IN THE THREE TYPES AT DIFFERENT PERIODS

Type of Kale.	9/2/40.		7/3/40.		16/4/40.	
	Leaf.	Stem.	Leaf.	Stem.	Leaf.	Stem.
Tall marrow-stem	47·2	52·8	43·3	56·7	33·7	66·3
Medium marrow-stem ..	56·4	43·6	47·0	53·0	42·7	57·3
Thousand-headed	76·2	23·8	73·8	26·2	66·8	33·2

Type of Kale.	13/5/40–11/6/40.		Average Percentage (Four Periods).		Average Yield in Lb./Plot (Four Periods).	
	Leaf.	Stem.	Leaf.	Stem.	Leaf.	Stem.
Tall marrow-stem	31·0	69·0	38·8	61·2	13·6	21·4
Medium marrow-stem ..	40·7	59·3	46·7	53·3	13·3	15·1
Thousand-headed	65·6	34·4	70·6	29·4	18·0	7·5

Comments on Table IV.—(i) In all cases the proportion of leaf to stem decreased as the plants matured, though to a lesser extent in thousand-headed kale than in the marrow-stem kale. This may be accounted for by the fact that as the marrow-stem kale plants mature the stem continues to develop, whereas the bulk of foliage is not increased proportionately, due in part to a shedding of the lower leaves.

(ii) At all periods thousand-headed kale gave the greatest proportion of leaf to stem and, over the four periods, the highest yield of leaf. The tall marrow-stem kale selection gave the lowest percentage of leaf and the highest percentage and yield of stem.

(d) *Stem Fractionation*

The stem of the kales is composed of three distinct layers: (*a*) the cortex, which for fractionation purposes included all tissues up to the xylem; (*b*) the xylem or wood; and (*c*) the pith or marrow (see Fig. 2). In order to determine the proportion of these components in the three types, ten representative plants were taken at each weighing and, from a similar

position along the length of the stems, a portion 3 in. long was removed and separated into cortex, wood, and marrow; these fractions were weighed and the percentage of each calculated. Results obtained are presented in Table V.

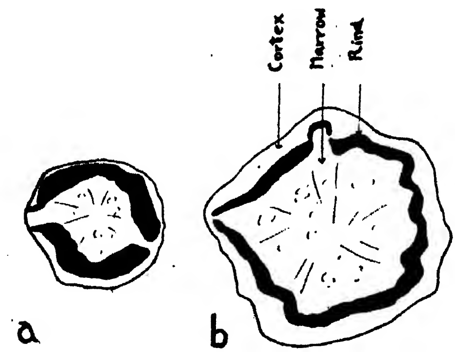


FIG. 2.—Diagrammatic cross-section of the stems of (a) thousand-headed kale; (b) marrow-stem kale, illustrating the relative proportions of cortex, rind or wood, and marrow.

TABLE V.—PERCENTAGES OF CORTEX, WOOD, AND MARROW, ON A GREEN-WEIGHT BASIS, IN THE STEMS OF THE THREE TYPES AT DIFFERENT PERIODS

Type of Kale.	9/2/40.			7/3/40.			16/4/40.		
	Cortex.	Wood.	Marrow.	Cortex.	Wood.	Marrow.	Cortex.	Wood.	Marrow.
Tall marrow-stem ..	27·3	16·8	55·9	28·4	18·4	53·2	26·6	23·4	50·0
Medium marrow-stem	30·3	15·2	54·5	26·3	19·9	53·8	30·3	21·1	48·6
Thousand-headed ..	32·4	23·1	44·5	31·6	32·9	35·5	28·7	39·1	32·2

Type of Kale.	13/5/40–11/6/40.			Average Percentage (Four Periods).			Average Yield of Marrow in Pounds per Plot (Four Periods).
	Cortex.	Wood.	Marrow.	Cortex.	Wood.	Marrow.	
Tall marrow-stem ..	26·4	20·0	53·6	27·2	19·6	53·2	11·4
Medium marrow-stem	27·5	22·0	50·5	28·6	19·6	51·8	7·9
Thousand-headed ..	31·0	34·6	34·4	31·0	32·4	36·6	2·7

Comments on Table V.—(i) In the marrow-stem kale types the marrow on an average constituted approximately 50 per cent. of the stem and the wood 20 per cent.; in the stem of thousand-headed kale there was approximately 36 per cent. marrow and 32 per cent. wood.

(ii) Between the marrow-stem kale types there was comparatively little difference in the percentages of each separate at each period. Over all periods, however, the tall marrow-stem kale type gave the highest yield of marrow.

(iii) In all types, as the crop matured, up to the third period the percentage of wood increased, while that of the marrow decreased; at the fourth period, excepting in the case of the medium marrow-stem kale type, there occurred a decrease in the percentage of wood.

(e) *Grazing*

To determine if there were any stock preference either for the leaf or for the stem amongst the three types, a grazing trial was carried out. As mentioned previously, six ewes were put on each series after the first records were taken. They were allowed to remain for approximately four days, when weighings and samplings were made of the grazed subplots; from the data obtained were calculated the percentages of leaf, stem, and total forage consumed during the four-day period, and the results obtained are presented in Table VI.

TABLE VI.—PERCENTAGES OF LEAF, STEM, AND TOTAL FORAGE GRAZED DURING FOUR DAYS FROM EACH TYPE AT DIFFERENT PERIODS

Type of Kale.	9/2/40.			7/3/40.			16/4/40.		
	Leaf.	Stem.	Total.	Leaf.	Stem.	Total.	Leaf.	Stem.	Total.
Tall marrow-stem ..	92·6	46·9	68·9	74·8	32·6	51·3	82·2	20·0	41·6
Medium marrow-stem	85·4	35·0	64·1	81·3	31·7	55·5	72·5	13·2	38·8
Thousand-headed ..	75·4	0	58·3	50·0	0	37·4	76·9	0	51·4

Type of Kale.	13/5/40–11/6/40.			Average Percentages and Amounts, in Pounds, per Plot consumed over Four Periods.					
	Leaf.	Stem.	Total.	Leaf.		Stem.		Total.	
				Per Cent.	lb.	Per Cent.	lb.	Per Cent.	lb.
Tall marrow-stem ..	68·4	29·4	41·8	79·5	10·8	32·2	6·9	50·9	17·7
Medium marrow-stem	48·6	13·4	27·7	71·9	9·6	23·3	3·5	46·5	13·1
Thousand-headed ..	82·0	0	54·7	71·0	12·8	0	0	50·4	12·8

Comments on Table VI.—(i) In the early stages the animals consumed a higher proportion of the leaf of the tall and medium marrow-stem kales than of the thousand-headed kale: in the later stages, however, this position was reversed. The development of fresh foliage in thousand-headed kale about the third period probably accounts for the greater percentage eaten at the last stage. These results tend to confirm the opinion recognized in practice that thousand-headed kale is suited more particularly for late feeding.

(ii) Over the four periods the sheep consumed a greater total weight of leaf of thousand-headed kale than of the marrow-stem kale.

(iii) The stem of the marrow-stem kale was eaten to a greater extent in the early stages than later; over all periods approximately 30 per cent. was consumed, whereas that of thousand-headed kale was untouched.

(iv) Over the four periods approximately equal proportions of the total forage available from each type were eaten; the greatest actual weight, however, was consumed from the tall marrow-stem kale type.

After weighing and sampling had been completed, the animals were again admitted to the plots and allowed to finish the grazing. Weighings were then taken of what stem remained, and from the figures obtained it was possible to calculate the percentage of leaf, stem, and total forage grazed finally from each type; the results are presented in Table VII.

TABLE VII.—PERCENTAGES OF LEAF, STEM, AND TOTAL FORAGE GRAZED FROM EACH TYPE AFTER THE FINAL FEEDINGS AT EACH PERIOD

Type of Kale.	9/2/40.			7/3/40.			16/4/40.		
	Leaf.	Stem.	Total.	Leaf.	Stem.	Total.	Leaf.	Stem.	Total.
Tall marrow-stem ..	100	80·3	89·6	100	63·4	79·6	100	66·1	78·3
Medium marrow-stem	100	66·0	85·2	100	68·3	83·1	100	51·7	72·1
Thousand-headed ..	100	29·5	83·1	100	0	74·1	100	25·5	75·2

Type of Kale.	13/5/40–11/6/40.			Average Percentage and Amounts in Pounds per Plot consumed over Four Periods.					
	Leaf.	Stem.	Total.	Leaf.		Stem.		Total.	
				Per Cent.	lb.	Per Cent.	lb.	Per Cent.	lb.
Tall marrow-stem ..	100	74·6	83·4	100	13·6	71·1	15·2	82·3	28·8
Medium marrow-stem	100	58·7	75·1	100	13·3	61·2	9·1	78·9	22·4
Thousand-headed ..	100	18·6	72·0	100	18·0	18·4	1·4	76·1	19·4

Comments on Table VII.—(i) At all stages 100 per cent. of the leaf of each type was eaten, which over the four periods is equivalent to an average of approximately 13 lb. per plot of the marrow-stem kale types and to an average of approximately 18 lb. per plot of the thousand-headed kale.

(ii) At each period the stem of the marrow-stem kale types was eaten to a greater extent than that of thousand-headed kale. Over the four periods the sheep consumed 71·1 per cent., or 15·2 lb., of the stem of the tall marrow-stem kale type, 61·2 per cent., or 9·1 lb., of the stem of the medium marrow-stem kale type, and 18·4 per cent., or 1·4 lb., of the stem of thousand-headed kale.

(iii) Of the total forage available from each type, approximately equal proportions were eaten over the four periods; in terms of actual amounts, though, the greatest weight (28·8 lb.) was consumed from the tall marrow-stem kale type.

(f) Chemical Composition and Nutritive Value

Although, as indicated previously, no chemical analyses were undertaken on samples from the trial plots, it is interesting to consider the above results in relation to the findings of Woodman, Evans, and Eden, who investigated in detail the composition of the kales, and in Table VIII are presented some data relating to the composition on the basis of absolute dry matter of leaf, marrow, and rind of singled-out marrow-stem kale.

TABLE VIII.—COMPOSITION (ON BASIS OF ABSOLUTE DRY MATTER) OF LEAF, MARROW, AND RIND OF SINGLED-OUT MARROW-STEM KALE (WOODMAN, EVANS, AND EDEN)

Fraction.	Dry Matter.	Crude Protein.	Ether Extract.	N-free Extract.	Crude Fibre.	Ash.	"Amides."
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Leaf	12·20	13·87	3·33	55·49	12·45	14·86	1·03
Marrow	8·57	12·03	1·34	58·38	13·06	15·18	3·98
Rind	16·54	7·72	0·81	55·34	29·08	7·05	1·69

These results indicate that the "leaf was the richest in crude protein (13·87 per cent. of the dry matter), the percentage of non-protein nitrogenous matter being quite small (1·03 per cent.). The rind contained the smallest percentage of crude protein, while the marrow (12·03 per cent.) was only slightly poorer than the leaf. The marrow, however, was much richer in 'amides' than either the leaf or rind, no less than 3·98 per cent. of its dry matter being composed of this simple form of nitrogen." In regard to ether extract, the leaves again contained the highest percentage, but were the poorest in crude fibre content, the most fibrous portion being the rind, the dry matter of which contained as much as 29·1 per cent.

Other results of Woodman, Evans, and Eden revealed the fact that the leaves are richest in lime and inorganic sulphur, while the marrow contained, on the dry-matter basis, the highest percentage of phosphoric acid, potash, soda, and magnesia.

From these results it would appear that in marrow-stem kale both the leaves and the marrow are quite nutritious, but that the rind is of low feeding-value. Thus it might be concluded that the most desirable type would be one composed of plants which possessed a high proportion of leaf to stem and which developed stems giving a high yield of marrow. Of the selections under review, the medium type has a higher proportion of leaf to stem than the tall type (Table IV), but this deficiency in the tall type is compensated for by the higher yield of marrow (Table V).

Woodman, Evans, and Eden also undertook a series of analyses of composite samples of marrow-stem kale and of thousand-headed kale, and the averages of some of the data they obtained are shown in Table IX.

TABLE IX.—COMPOSITION ON BASIS OF DRY MATTER OF COMPOSITE SAMPLES OF MARROW-STEM KALE AND OF THOUSAND-HEADED KALE

Type of Kale.	Dry Matter.	Crude Protein.	Ether Extract.	N-free Extract.	Crude Fibre.	Ash.	"Amides."
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Marrow-stem ..	13·3	15·01	2·90	50·61	18·27	13·20	4·30
Thousand-headed ..	15·8	13·55	2·39	53·57	19·88	10·60	3·64

These results indicate a close resemblance in chemical composition, on the basis of dry matter, between composite samples of marrow-stem kale and of thousand-headed kale, and it could be inferred that their feeding-value depends largely on the total yield of dry matter per acre produced by each. Thousand-headed kale has a higher dry-matter percentage than marrow-stem kale, but this advantage is minimized by its lower total green-weight yield (Table III).

In respect to the composition of kales, Woodman, Evans, and Eden state "that an important finding was the discovery of their very high content of mineral matter, which is distinguished by its richness in lime, chlorine, potash, and sulphur. Satisfactory amounts of iron and magnesia together with an amount of phosphoric acid about equal to that in flowering lucerne are also present. As a source of minerals the kale crops are very much superior to swedes."

DISCUSSION

As the results presented have been obtained from only one trial in one locality it is evident that they must be regarded with due caution; nevertheless, they do provide some indication as to the comparative behaviour of the different types.

When the trials were arranged it was considered that it might be possible to determine which of the types might be the most satisfactory for forage purposes. From the results, though, it is somewhat difficult to differentiate between the three. Each is a useful fodder plant, and although the tall marrow-stem kale type gave the highest total yield, the highest dry-matter yield, and had the greatest total amount consumed, yet thousand-headed kale gave the highest dry-matter percentage, the highest percentage and yield of leaf, and had the greatest amount of leaf eaten. In the absence, therefore, of data relating to the effect of each type on the animal itself it is not an easy matter to determine which might have the highest feeding-value. Each, however, might serve some particular purpose of its own; for instance, it is possible that the tall marrow-stem kale type might be most suited for feeding cattle during the late autumn and early winter, the medium marrow-stem kale type for feeding sheep during a similar period, and thousand-headed kale, in accordance with present custom, for feeding both cattle and sheep in the late winter and early spring.

Seed-supplies of each of the three selected types have been built up and are to be distributed commercially through the certification scheme administered by the Department of Agriculture. To differentiate them from commercial stocks, the tall marrow-stem kale type is to be known as "Government certified giant chou moellier," the medium marrow-stem kale type as "Government certified medium-stemmed chou moellier," and the thousand-headed kale as "Government certified thousand-headed kale."

REFERENCES

(1) *Statistical Reports on the Agric. & Past. Prod. of the Dominion of N.Z.*
(2) CALDER, R. A. (1939): *N.Z. Jour. Sci. & Tech.*, *21*, 223A–9A.
(3) WOODMAN, EVANS, and EDEN (1936): *Jour. Agric. Sci.*, *26*, 212.

THE NEW ZEALAND
JOURNAL OF SCIENCE
AND
TECHNOLOGY

Editor: D. Cairns, M.Sc., Department of Scientific and Industrial Research, Wellington

VOL. 26, SEC. A AUGUST, 1944 NUMBER 2

CANTERBURY LAMB

By D. E. WALKER and C. P. McMEEKAN, Animal Research Station, Department of Agriculture, Ruakura, Hamilton

Summary

(1) Certain relationships between linear carcass measurements and the quantitative composition of the carcass have been established.

(2) Attention has been given chiefly to the use of external measurements to provide indices of carcass composition.

(3) Certain internal measurements have an important qualitative significance, although they are not necessarily associated with the gross composition of the carcass.

(4) External measurements provided several suitable indices of muscle development. Length of tibia + tarsus × width of gigots yielded the highest correlation coefficient. "Length" of "eye muscle" was the only internal measurement tested which gave a significant correlation with muscle.

(5) Four of Palsson's highest correlations between measurements and the muscle : bone ratio have been tested in respect to Canterbury lamb. Two of these proved highly significant and the other two not significant.

(6) The total weight of bone in the carcass (excluding head and feet) was found to be strongly correlated with the total weight of muscle.

(7) The external measurements that show strong correlations with muscle will therefore be correlated with bone. Since such measurements are mainly indicative of skeletal development, the correlations are likely to be stronger in respect to bone. This has been shown to be so in the case of length of tibia + tarsus × width of gigots, which thus provides a good index of both bone and muscle.

(8) Length of tibia + tarsus × width of gigots has been tested for both bone and muscle in the two main lines of North Island lamb and its validity established.

(9) No direct or indirect correlation between external measurements and fat in the carcass was found. Palsson's negative correlation for leg length against fat expressed as a percentage of bone did not hold for Canterbury lamb.

(10) It is suggested that since reliable indices of muscle and bone are available, and the average percentage of waste is known from dissection results, the figure for fat can best be derived by calculating the difference between carcass weight − waste and the estimated weight of muscle + bone.

INTRODUCTION

The study of form may be descriptive merely, or it may become analytical. We begin by describing the shape of an object in the simple words of common speech; we end by defining it in the precise language of mathematics; and the one method tends to follow the other in strict scientific order and historical continuity.—D'ARCY THOMPSON(1).

need of comparable foundation work for each population. An attempt has been made in Part I to establish such criteria for New Zealand Canterbury lamb.

Carcass measurements, alone, have proved of some use in evaluating breed differences (Palsson(6), Hirzel(8), and Bonsma(9) in sheep; Hankins *et al.*(10) in beef and dual-purpose cattle). Various measurements on different breeds and crosses of Canterbury lambs have been analysed in Part II to provide a measure of the variance which exists between different populations. The data have permitted examination of the effect of sex and nutrition.

Since nutrition is the major environmental factor producing variation in animal form and composition, opportunity has been taken of measuring the variances in different breeds and crosses raised under "identical" conditions. The results, reported in Part III, are of direct interest in relation to problems associated with breeding and feeding, where control of environmental effects is important. The same data have provided information on the rate of growth of New Zealand fat lambs under a high plane of nutrition conditions.

PART I.—CARCASS MEASUREMENTS AS INDICES OF QUALITY

In the study of the meat animal the linear measurements commonly employed fall into two main classes: (*a*) External; (*b*) internal. In general, external measures are descriptive of body form or conformation, and particularly of skeletal development. On the other hand, internal measures are more useful as indices of composition—*i.e.*, of the relative proportion of bone, muscle, and fat. Both types of measurement must be employed in the study of meat quality, since both conformation and composition are of importance.

Some measures have dominantly a qualitative significance; others are justifiable on quantitative grounds. A good example of the former type is the "thickness" of the longissimus dorsi muscle. This measure has no direct quantitative relationship to muscle development, though a "deep eye muscle" appears larger than a shallow one. The optical illusion thus created confers a market superiority on the deep-muscled carcass which its actual amount of muscle may not warrant. In like manner, the length of leg is of importance in being related to the shape of the hindquarters, which tend to be more blocky, yielding larger cuts of meat than long-legged carcasses.

On the other hand, an example of a measure having mainly a quantitative significance is the length of the "cannon" bone. Though this bone is removed as waste at slaughter and thus has no qualitative significance to the consumer, it is a useful index of the amount of bone in the carcass.

The importance of many of the so-called "purely qualitative" measures is largely a matter of opinion, while their significance undoubtedly varies in different markets and even in the same market at different times. The "quantitative" aspects of meat quality, however, are of more stable value. In this section the relationship of certain readily obtainable measurements to carcass composition is therefore the main concern. Attention has been limited to external measurements, since it is not practicable under commercial conditions to obtain internal measurements of fat-lamb carcasses.

An investigation into the nutritive value of New Zealand export-quality lamb and mutton was recently undertaken by New Zealand workers(3). In the course of this investigation carcass measurements were taken and complete anatomical dissection carried out on groups of carcasses representative of the main export grades. Some of the lamb data obtained have provided the material for the following study.

Canterbury lamb is graded according to weight and quality of the carcasses :—

Prime-quality Lambs—

24–36 lb.	Grade mark 2
37–42 lb.	„ 8
43–50 lb.	„ 4

Second-quality lambs—

Under 37 lb.	Grade mark Y1 or Y.
Over 37 lb.	„ Y2 or YH.

Ten carcasses from each grade were selected for dissection after three months in cold store. One "bay" of five hundred lambs per weight grade was selected at random in the Islington Freezing-works, Canterbury. The ten carcasses were selected from each bay at random on a restricted weight basis so that the complete range of weight of the grade was represented, and the average weight of the ten equalled the average weight of the grade. Each series of ten included three carcasses of the Down Cross type to cover the 30 per cent. such carcasses normally included in "Canterbury" or South Island lambs.

In this section grades 2 and 8 Canterbury lambs have been more specifically dealt with, since the carcasses involved in the breed study of Part II fall into these two grades. However, the most satisfactory correlations have been extended to embrace Grade 4 lambs to cover the complete range of first-quality export lamb. Further, the Kirwee lambs dealt with in Part III, to which these correlations have been applied, include lambs within all three weight grades.

To test the validity of the chief relationships, similar correlations have been calculated for North Island Prime Cross and Down Cross lambs.

It will be noted (Tables I–V) that the number of lambs involved in each grade fall short of ten in certain cases. This is due to the omission of carcasses for which relevant measurement data were not available.

The method of analysis used has been one of simple correlation on the basis of absolute values for both variates. Regression equations have been calculated where the correlation coefficients are most significant.

The technique followed in the dissection work and the method of obtaining the various measurements used in this and in other parts of this study have been described by Palsson(6) and the same nomenclature has been employed. This is as follows (see sketch on following page):—

External Measurements—

F = leg length.

G = width of gigots.

L = length of body from the symphysis pubis to the anterior edge of the middle of the first rib.

M = length of the fore cannon (metacarpal).

T = length of tibia + tarsus from the tubercle on the proximal end of the tibia to the anterior edge of the distal end of the tarsal.

Th = depth of thorax. The maximum depth of chest behind the shoulders.

Internal Measurements (on cross-section at last rib) :—

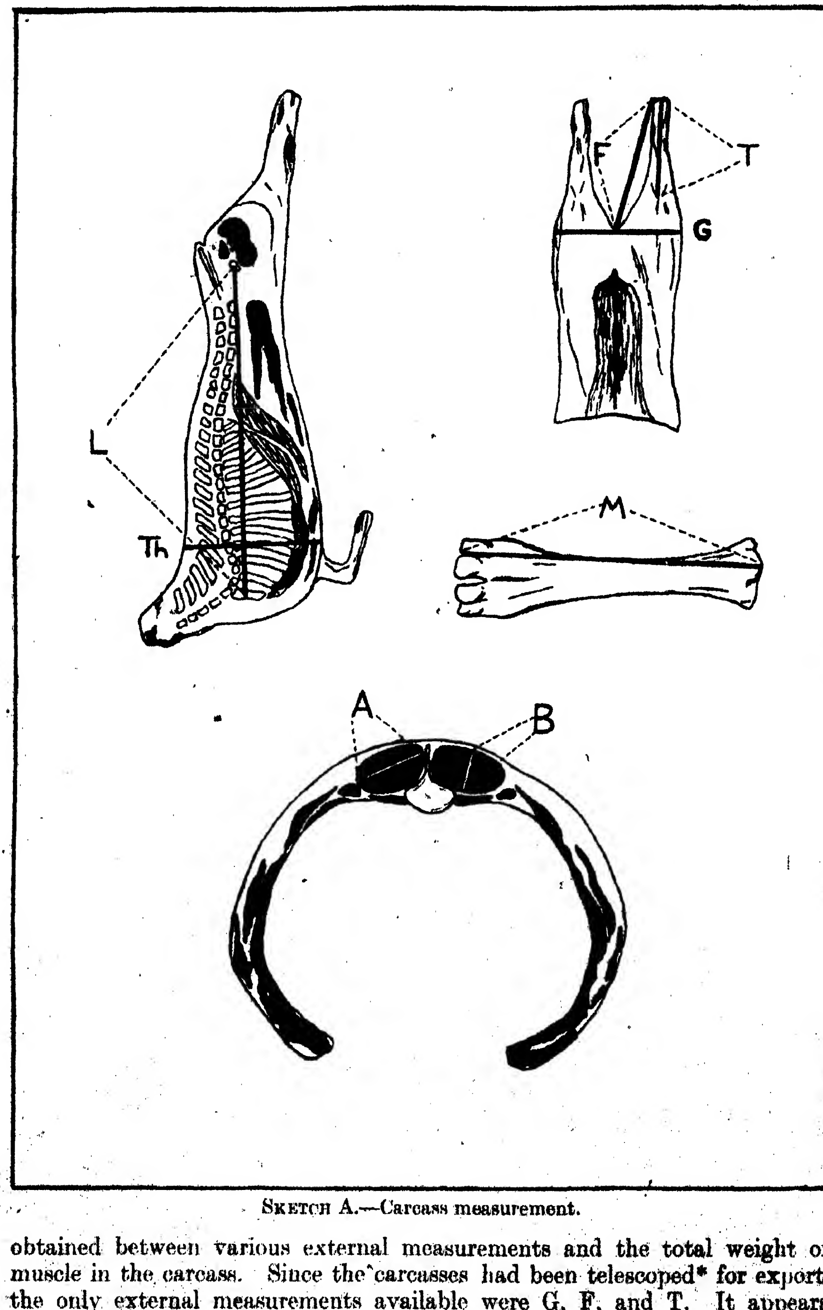
A = "length" of "eye muscle"—the maximum distance across the cross-section surface of the longissimus dorsi from the end next the spinal process outwards along the rib.

B = "depth" of "eye muscle"—the greatest distance at right angles to A on the same surface.

A. MEASUREMENTS AS INDICES OF THE AMOUNT OF MUSCLE

(1) *External Measurements*

Although these are essentially more indicative of skeletal size than of muscle or fat development, several highly-significant correlations have been



SKETCH A.—Carcass measurement.

obtained between various external measurements and the total weight of muscle in the carcass. Since the carcasses had been telescoped* for export, the only external measurements available were G, F, and T. It appears

* For the duration of the war carcasses are halved and packed with the hind-quarters "telescoping" into the forequarters in order to conserve shipping space.

that F in such cases is not a very reliable measurement to use, since the telescoping is liable to result in some degree of distortion. This was noticeable in data relating to some of the North Island lambs, although as regards the Canterbury lambs the F measurements obtained agreed satisfactorily with those collected on other comparable lines (see Part II). However, the most highly significant correlations obtained did not involve the use of F. Table I shows the different correlations.

TABLE I.—CORRELATION BETWEEN EXTERNAL CARCASS MEASUREMENTS AND WEIGHT OF MUSCLE (GRAMS), (EXCLUDING HEAD AND FEET)

Population.*	Number of Pairs.	Measurement.	r.	P.	Regression Equation (Grams).	Standard Error of Estimate (Grams).
Canterbury lambs—						
2's and 8's ..	18	T × G	0·894	SS	X = 0·257Y − 1,758	486
2's, 8's, and 4's ..	28	T × G	0·872	SS	X = 0·286Y − 2,652	826
Palsson's data—						
Lambs	11	T × G	0·513	NS	..	..
Canterbury lambs—						
2's and 8's ..	18	F × T	0·802	SS	..	..
2's and 8's ..	18	T	0·718	SS	..	..
2's and 8's ..	18	$\frac{F \times T}{G}$	0·717	SS	..	..
2's and 8's ..	18	G	0·672	SS	..	..
2's and 8's ..	18	F	0·746	SS	..	..

* For North Island Down Cross lambs (2's, 8's, and 4's) r = 0·898 for the T × G measurement, and for North Island Prime lambs (2's, 8's, and 4's) r = 0·907 (from data supplied by E. A. Clarke).

The measurement T × G in all groups yielded a highly-significant correlation with total muscle weight. F, F × T, T, $\frac{F \times T}{G}$, and G also showed significant correlations of a lower order.

(2) *Internal Measurements*

The relationships between a few internal measurements and the total weight of muscle or the total weight of muscle expressed as a percentage of the skeletal weight have been investigated, and the results are shown in Tables II and III.

TABLE II.—CORRELATION BETWEEN INTERNAL MEASUREMENTS AND WEIGHT OF MUSCLE (GRAMS)

Canterbury Lamb.					*Palsson's Figures for Comparison.*			
Population.	Number of Pairs.	Measurement.	r.	P.	Population.	Number of Pairs.	r.	P.
Canterbury lamb—					Various breeds and crosses—			
2's and 8's ..	17	A	0·741	SS	Lambs, 43 lb.	11	0·674	S
2's and 8's ..	17	B	0·185	NS	Lambs, 43 lb.	11	0·468	NS
2's and 8's ..	17	A × B	0·188	NS				

Length of the eye muscle, A, is an early-developing characteristic and as such may be expected to provide a reasonably-good indication of general muscle development since it is measured in the late-developing loin region. This was found to be the case. The correlation coefficient, although not of particularly high order, is strongly significant.

McMeekan(5) found A × B, an approximation of the surface area of the "eye," to show a fairly high correlation with total weight of muscle in bacon pigs. However, this correlation in respect to lambs was not significant.

Depth of eye muscle, B, is a later-developing feature and hence, in lambs, cannot be expected to provide a direct satisfactory index of muscle development. The correlation coefficient in this case is low, and is obviously not significant. However, B correlates significantly with the muscle : bone ratio as shown in Table III. The shape index $\frac{B}{A} \times 100$, and also the depth B, have been extensively used by different workers in studying meat qualities. The emphasis laid on these measurements can be justified from the qualitative rather than the quantitative point of view. Although there may be no direct correlation between these measurements and carcass composition, nevertheless they are important in themselves. A good depth of muscle and a high ratio of depth to length in this region is essential from the commercial point of view. The loin is the most valuable part of the carcass, and it is the shape rather than the area of muscle which determines its suitability for high-quality and high-priced trade. While B provides a strongly significant correlation coefficient with the muscle : bone ratio, the correlation between $\frac{B}{A} \times 100$ and either the total weight of muscle alone or expressed as a percentage of the skeletal weight is not significant.

TABLE III.—CORRELATION BETWEEN MEASUREMENTS AND WEIGHT OF MUSCLE EXPRESSED AS A PERCENTAGE OF WEIGHT OF BONE

Canterbury Lamb.					*Palsson's Figures for Comparison.*			
Population.	Number of Pairs.	Measurement.	r.	P.	Population	Number of Pairs.	r.	P.
Canterbury lamb—					Various breeds and crosses—			
2's and 8's ..	18	F — T	−0·408	NS	Lambs, 43 lb.	11	−0·933	SS
2's and 8's ..	18	$\frac{G}{F} \times 100$	+0·609	SS	Lambs, 43 lb.	11	+0·869	SS
2's and 8's ..	17	B	+0·875	SS	Lambs, 43 lb.	11	+0·714	S
2's and 8's ..	17	$\frac{B}{A} \times 100$	+0·108	NS	Lambs, 43 lb.	11	+0·800	SS

The formulæ used by Palsson in determining his two highest correlations between external measurements and the muscle : bone ratio have been tested out in application to Canterbury grades 2 and 8 lambs. The results are shown in Table III. F — T, which Palsson found to be strongly correlated negatively with the total weight of muscle expressed as a percentage of the total weight of skeleton, provided only a non-significant negative correlation for Canterbury lamb. $\frac{G}{F} \times 100$, however, gave a strongly-significant positive correlation, though of rather low order—appreciably lower than Palsson's. On the other hand, T × G, which provided the most satisfactory index of muscle development, in Canterbury lamb gave a non-significant correlation when tested out with Palsson's data (Table I).

In respect to internal measurements, the correlation between B and the muscle : bone ratio was significant at the 1 per cent. level for Canterbury lamb and at the 2 per cent. level for Palsson's material. $\frac{B}{A} \times 100$, however, gave only a non-significant correlation for Canterbury lamb, whereas Palsson obtained a highly-significant correlation. For direct correlations with muscle the coefficients obtained with B were not significant in either case, while A was significant at the 1 per cent. level for Canterbury lamb and at the 5 per cent. level for Palsson's material (Table II).

Although there is a difference between the carcass weights of the Canterbury lamb (grades 2 and 8 : 24–42 lb. : and grades 2, 8, and 4 : 24–50 lb.) and the material used by Palsson (all approximately 43 lb.), it is considered that the main reason for the difference in the results is the variability due to breed existing in Palsson's material. It would appear that the relationships established by him were largely fortuitous.

B. MEASUREMENTS AS INDICES OF THE AMOUNT OF BONE

A high correlation ($r = 0{\cdot}9296$) was obtained between the total weight of bone in the carcass (excluding head and feet) and the total weight of muscle.

TABLE IV.—CORRELATION BETWEEN TOTAL WEIGHT OF BONE AND TOTAL WEIGHT OF MUSCLE (GRAMS)

Population.	Number of Pairs.	Measurement.	r.	P.	S_e (Grams)
Canterbury lamb— 2's and 8's	18	Total weight of bone ..	0·930	SS	401

This supports the contention that skeletal development is a prerequisite for maximum muscular development. In view of this fact, such correlations as hold between the various measurements and the total weight of muscle may be expected to hold for the total weight of bone. The T × G formula, which proved to be the most satisfactory index of muscle development, was found to have an even higher correlation with the total weight of bone. Since carcass measurements are mainly indicative of skeletal development, this is as might be expected.

TABLE V.—CORRELATION BETWEEN EXTERNAL CARCASS MEASUREMENTS AND WEIGHT OF BONE (GRAMS)

Population*.	Number of Pairs.	Measurements.	r.	P.	Regression Equation (Grams).	S_e (Grams)
Canterbury lambs—						
2's and 8's	18	T × G	0·934	SS	$X = 0{\cdot}0865Y - 1{,}364$	125
2's, 8's, and 4's ..	28	T × G	0·913	SS	$X = 0{\cdot}063Y - 525$..	145
2's, 8's, and 4's ..	28	T	0·799	SS	..	..

* For North Island Down Cross lambs (2's, 8's, and 4's) $r = 0{\cdot}816$ for the T × G measurement, and for North Island Prime Cross lambs (2's, 8's, and 4's) $r = 0{\cdot}909$.

In view of the strength of the T × G correlation, and as the convenience of employing the same measurements for both bone and muscle estimation is obvious, no further correlations were calculated except that between T and total bone. The cannon bones, which have been used to provide indices of skeletal growth (Hammond(2), Palsson(6) in sheep; McMeekan(5) in pigs) were not available.

The T × G correlation has been tested out on the two lines of North Island lambs. Here the correlation coefficients were also strongly significant.

C. MEASUREMENTS AS INDICES OF THE AMOUNT OF FAT

Since fat deposits are largely independent of skeletal development, and since the primary dimension in regard to fat depots is that of depth, it would be unreasonable to expect any close association between linear carcass measurements and the total amount of fat in the carcass. Any such correlations as might exist would necessarily be purely fortuitous. In this investigation no correlations were obtained between external measurements and the total weight of fat in carcasses. Internal measurements (such as those relating to fat depths at the last rib cut) undoubtedly offer better scope, but they have not been considered here owing to the impracticability of obtaining them except under special conditions. The aim has been to provide indices which do not involve cutting the carcass and which can be obtained under commercial conditions.

The best method that can be suggested for estimating the amount of fat is that of difference between the total carcass weight and the weight of bone + muscle after allowing 2·5 per cent. off the carcass weight for wastage (tendons, ligaments, &c.). This figure is based on the actual dissection results of approximately one hundred and twenty lambs of all weights and grades(13). Calculations by this method approximate very closely to the weights obtained in dissection.

Palsson found a highly-significant negative correlation to exist between F and the weight of fat expressed as a percentage of the weight of bones. There is no correlation between similar data for Canterbury lamb.

REFERENCES

(1) THOMPSON, D'ARCY (1917): "Growth and Form." Cambridge Univ. Press.
(2) HAMMOND, J. (1932): "Growth and Development of Mutton Qualities in the Sheep." Oliver and Boyd, Edinburgh.
(3) McMEEKAN, C. P., and CLARKE, E. A. (1943): *Roy. Agr. Soc. of N.Z. Gazette No. 47.*
(4) McMEEKAN, C. P. (1940): *J. Agr. Sci. 30*, 276.
(5) ——— (1941): *J. Agr. Sci. 31*, 1.
(6) PALSSON, H. (1939): *J. Agr. Sci. 29*, 544. (1940): *Ibid., 30*, 1.
(7) VERGES, J. (1939): Suffolk Sheep Society Year-Books.
(8) HIRZEL, R. (1939): *Onders, J. Vet. Sci. and An. Ind. 12*, 379.
(9) BONSMA, F. N. (1939): *Univ. of Pretoria Bull. 48.*
(10) HANKINS, O. G., *et al.* (1943): *J. An. Sci. 2*, 42.
(11) WALLACE, L. R. (1940): Thesis Massey Agr. College.
(12) McMEEKAN, C. P.: Unpublished data.

PART II.—COMPARATIVE MEASUREMENTS OF CANTERBURY LAMB

Summary

(1) With the object of obtaining factual data on "Canterbury lamb" of export quality, large samples representative of the more important types have been studied, using the carcass-measurement technique of Palsson(6).

(2) The material available has permitted a comparison of the three major breeds—Corriedale, Southdown × Corriedale, and Romney × Corriedale—at both light and heavy weights. The superiority of Southdown Cross lambs has been demonstrated.

(3) Comparative carcass data is also presented of lambs fattened off the mother (milk lambs) and lambs fattened on rape after weaning (rape lambs). Breed has been shown to influence the response to method of feeding. Southdown Cross lambs improve slightly under rape feeding, and Corriedale lambs deteriorate in quality. Thus the superiority of the Southdown Cross lambs over the Corriedale appears to apply with even greater effect where rape fattening is necessary.

(4) The effect of sex upon carcass quality in fat lambs has also been evaluated. Differences between ewe and wether lambs exist, but appear to be of minor economic importance in the breeds, crosses, and weights studied.

FAT-LAMB production in Canterbury is based upon the use of the so-called "fine-woolled" ewe. Ideally suited by virtue of comparatively poor nutritive conditions to the growth of this type of wool, the Canterbury Plains have become dominantly stocked by the small-bodied Corriedale—a breed derived from a Merino-Lincoln-Leicester base. Ewes of this breed become the mothers of fat lambs. On the better-class country, "cast for age" ewes are mated to the Southdown ram for specialized fat-lamb production, all progeny being slaughtered. From the sheep-breeding country and from lowland farms employing self-maintaining flocks, wether Corriedale lambs are likewise disposed of. These two classes comprise the bulk of the export lamb. Of recent years improved pastures on the foothill country have enabled the use of the Romney breed, and Romney × Corriedale lambs now come forward in fairly large numbers.

Data on these three major types are treated in this section. The English Leicester, which was the principal fat-lamb sire bred with the fine-woolled ewe in the initial stages of the industry, is now of minor importance, having been almost completely replaced by the S.D. The B.L. Cross lamb is still produced, but is of importance mainly in respect to the local market, since lambs of this cross are best marketable at heavy weights unacceptable to the London trade. Illustrations of the late-developing characteristics of the B.L. Cross will be available in Part III of this paper.

While the relative merits, based on farmer experience and works grading, are fairly well recognized, no attempt has yet been made to examine these breeds on a comparative measurement basis. Lack of factual information here is adequate justification for the present study.

In addition to breed differences, Canterbury fat-lamb production is characterized by two types of lamb on a nutritive basis. Approximately half of the output is fattened off the mothers—the so-called "milk lambs"—while the remainder are fattened after weaning on forage crops—the so-called "rape lambs." Differences in quality arise from this cause, but, like breed differences, have never been the subject of careful investigation.

The sheep studied were raised on the farms of the Canterbury Agricultural College (Lincoln and Ashley Dene) and of the Department of Agriculture (Kirwee) and may be considered typical of the average Canterbury product. All lambs were picked for slaughter by a fat-lamb buyer as in normal commercial practice, individually identified by ear tag, and slaughtered at the Kaiapoi works of the North Canterbury Farmers' Freezing Co.

The external measurements described in Part I were taken on each carcass using a millimetre scale. The data have been examined on a basis of breed, weight, feed, and sex. The weight grouping compares approximately to the commercial grades 2's and 8's. The significance of differences observed has been tested by standard analysis of variance techniques. Throughout the following report any "differences" in carcass measurements to which reference is made are statistically significant. Reference to the appropriate tables will indicate the level of significance of any difference.

THE INFLUENCE OF BREED, WEIGHT, AND FATTENING SYSTEM

In the following comparisons light-weight lambs with a range in carcass weight from 32 lb. to 36 lb. are designated "light"; heavier lambs ranging from 36·1 lb. to 42 lb. are designated "heavy." Lambs fattened off the mother are designated "milk," and those fattened on rape after weaning are referred to as "rape" lambs.

(*a*) *Width of Gigots (G)*.—This measurement, alone or in combination with others, is highly correlated with the composition of the carcass (Part I). Essentially, it provides an index of the development of the hindquarters. Wide gigots are desirable from the point of view of conformation, so that this measurement has both a qualitative and quantitative importance.

The heavy-weight lambs are wider in the gigots than the light-weights of the same breed group. Amongst the light-weight lambs the S.D. Cross group shows a slightly better development in the gigots than the other breed groups, while amongst the heavy-weight lambs the Corriedales have the widest gigots, although the difference between this group and the comparable Romney × Corriedale is not significant. There is no difference in gigot development between the heavy S.D. Cross lambs and the heavy Romney × Corriedale lambs. These differences are in line with the late-developing character of this measurement(6).

TABLE VIA.—INFLUENCE OF BREED AND WEIGHT ON WIDTH OF GIGOTS (G) (MILLIMETRES)
(Mean measurements (millimetres) and significance of differences)

—	S.D. Cross.		Corriedale.		Romney × Corriedale.		S.E. of Mean.	Number in Group
	Light.	Heavy.	Light.	Heavy.	Light.	Heavy.		
S.D. Cross—								
Light ..	219·75	SS	S	SS	S	S	0·47	185
Heavy ..	..	223·17	SS	SS	SS	NS	0·51	157
Corriedale—								
Light ..	..	..	218·07	SS	NS	SS	0·65	97
Heavy ..	..	..	..	226·31	SS	NS	0·60	111
Romney × Corriedale—								
Light ..	..	..	..	..	217·29	SS	0·95	45
Heavy ..	..	..	..	..	..	223·24	1·54	17

SS = significant at 1 per cent. level; S = significant at 5 per cent. level; NS = not significant.

It will be noted that the differences recorded in width of gigots average only 1 mm. to 3 mm., an amount that might be expected to be difficult to distinguish by eye judgment and therefore of little practical moment. Yet even a casual observer will readily place S.D. × Corriedale lambs as having larger and better developed hindquarters than Corriedale lambs of the same weight. Indeed, the differences readily apparent here largely determine the commercial grading of a carcass as "Down Cross" or "Prime Cross," the two major quality grades of New Zealand fat lamb. This situation emphasizes the very great difficulty of expressing, in terms of a single linear measurement, a character, such as development of hindquarters, that exists in three dimensions. This same difficulty applies to all linear carcass measurements and must be taken into account in examining our data. Even small differences are often indicative of very significant carcass differences, and the fact that variations in form can be evaluated at all in terms of a single linear measure should be counted of distinct practical importance.

TABLE VIB.—INFLUENCE OF FATTENING SYSTEM ON WIDTH OF GIGOTS (G) (MILLIMETRES)

(Mean measurements (millimetres) and significance of differences)

	S.D. Cross.		Corriedale.		S.E. of Mean.	Number in Group.
	Milk.	Rape.	Milk.	Rape.		
S.D. Cross—						
Milk	221·32	SS	S	SS	0·37	342
Rape	..	223·61	NS	SS	0·73	87
Corriedale—						
Milk	..	..	222·47	SS	0·47	208
Rape	..	..	..	219·18	0·69	99

SS = significant at 1 per cent. level; S = significant at 5 per cent. level; NS = not significant.

The differences between the milk- and rape-fattened lambs within each breed group are highly significant, although not as marked as those existing between the light- and heavy-weight lambs (Table VIB). Rape-fattened S.D. Cross lambs are wider in the gigots than the milk lambs whereas the rape-fattened Corriedales are narrower than those fattened off the mothers. The Corriedales fattened off the mothers are wider in G than the comparable S.D. Cross lambs. The gigot width in the rape-fattened Corriedales, however, is less than that of the rape-fattened S.D. Cross lambs. It appears that backward Corriedale lambs do not benefit to the same extent as backward S.D. Cross lambs when fattened on rape after weaning.

(b) *Length of Tibia and Tarsus (T).*—T alone is highly correlated with both total bone and muscle of the carcass. In combination with F and/or G, this measurement provides an even more efficient index of bone and muscle (see Part I). While a long T measurement is thus necessary for maximum muscle development of the carcass, it is unfortunate that great length in this part is associated with a badly-shaped and poorly-filled leg. In this character, therefore, the demands of quality and quantity conflict, and an "optimum" length of T must be sought which strikes a balance between composition and conformation. Thus, although the S.D. Cross provides the most desirable type of leg joint from a conformation viewpoint, a Corriedale carcass of the same weight carries more muscle.

Breed differences in regard to T may be very marked. The Corriedale is notoriously "long in the leg," yielding a poorly-shaped joint. On the other hand, the S.D. Cross lamb inherits the short leg of the S.D. and the leg joint is of the desirable "blocky" type. The Romney × Corriedale falls intermediate in leg length between these two types, although the heavy-weight lambs in this group approximate in length of T to the light-weight Corriedales.

Light-weight lambs within each breed group are shorter in T than heavy-weights.

T is a measure of an early-developing character(6). Accordingly, the heavy S.D. Cross lambs do not show such a marked increase over the light-weights in this respect as is found between the comparable classes of the later-maturing Corriedale.

TABLE VIIA.—INFLUENCE OF BREED AND WEIGHT ON LENGTH OF TIBIA + TARSUS (T)
(Mean measurements (millimetres) and significance of differences)

—	S.D. Cross.		Corriedale.		Romney × Corriedale.		S.E. of Mean.	Number in Group.
	Light.	Heavy.	Light.	Heavy.	Light.	Heavy.		
S.D. Cross—								
Light ..	175·08	SS	SS	SS	SS	SS	0·54	185
Heavy ..	..	178·76	SS	SS	SS	SS	0·58	157
Corriedale—								
Light ..	..	..	189·88	SS	SS	NS	0·74	97
Heavy ..	..	..	..	195·17	SS	S	0·69	111
Romney × Corriedale—								
Light ..	..	..	..	..	184·62	SS	1·09	45
Heavy ..	..	..	..	..	..	191·18	1·77	17

SS = significant at 1 per cent. level; S = significant at 5 per cent. level; NS = not significant.

Feed differences in this measurement are not marked, breed appearing to be much more important (Table VIIB). Rape-fattened Corriedales do not differ in T from those fattened off their mothers. The difference between the milk- and the rape-fattened S.D. Cross lambs, however, is significant, the latter being appreciably longer in T. Since T is an early-developing character, it would appear that the S.D. Cross lambs which have suffered a setback in some form necessitating rape fattening either lose some of the early-maturing capacity of the S.D. or have not inherited it to the same extent as lambs which fatten off their mothers. Either explanation fits the approach of rape-fattened S.D. Cross lambs towards the Corriedale type.

TABLE VIIB.—INFLUENCE OF FATTENING SYSTEM ON LENGTH OF TIBIA + TARSUS (T)
(Mean measurements (millimetres) and significance of differences)

—	S.D. Cross.		Corriedale.		S.E. of Mean.	Number in Group.
	Milk.	Rape.	Milk.	Rape.		
S.D. Cross—						
Milk	176·77	SS	SS	SS	0·42	342
Rape	..	179·72	SS	SS	0·84	87
Corriedale—						
Milk	..	..	192·70	NS	0·54	208
Rape	..	..	..	192·88	0·79	99

SS = significant at 1 per cent. level; S = significant at 5 per cent. level; NS = not significant.

(*c*) *Product of Length of Tibia + Tarsus and Width of Gigots* ($T \times G$).—This formula has been found to provide the most satisfactory index of both the total weight of muscle and the total weight of bone in the carcass (Part I).

Table VIIIA shows the product of the means of T × G for each group. The differences are all strongly significant. The light lambs within each breed group have a smaller T × G than the heavy lambs. The light S.D. Cross lambs have the lowest measure and the heavy Corriedales the highest, with the Romney × Corriedales occupying intermediate positions. So that, although the S.D. Cross lamb has the superior carcass from the point of view of conformation and finish, the Corriedale carcass actually carries more muscle, while the Romney × Corriedale tends to fall intermediate both in conformation and composition.

TABLE VIIIA.—INFLUENCE OF BREED AND WEIGHT ON T × G
(Mean measurements (millimetres) and significance of differences)

—	S.D. Cross.		Corriedale.		Romney × Corriedale.	
	Light	Heavy.	Light.	Heavy.	Light.	Heavy.
S.D. Cross—						
Light	38,474	SS	SS	SS	SS	SS
Heavy	..	39,894	SS	SS	SS	SS
Corriedale—						
Light	..	..	41,407	SS	SS	SS
Heavy	..	..	..	44,169	SS	SS
Romney × Corriedale—						
Light	..	..	..	..	40,116	SS
Heavy	..	..	..	..	..	42,679

SS = significant at 1 per cent. level; S = significant at 5 per cent. level; NS = not significant.

Differences between the breed and feed groups are all highly significant (Table VIIIB). Amongst the S.D. Cross lambs the rape-fed group has the higher T × G measure, while amongst the Corriedales the milk-fattened lambs are higher. A possible explanation of this difference is that the S.D. Cross lambs which do not fatten off their mothers inherit the early-maturing propensity of the S.D. to a lesser degree and tend to approach the Corriedale type. Hence the few extra weeks on forage crops allow them to attain fuller development. Alternatively, lambs of the normal S.D. Cross type which have suffered some setback necessitating rape fattening may be able to benefit to a greater extent when placed on a high plane of nutrition after weaning than can backward Corriedales. The Corriedale does not yield a very desirable type of carcass under the best of conditions, and where any setback has been experienced a very poor carcass usually results.

TABLE VIIIB.—INFLUENCE OF FATTENING SYSTEM ON T × G
(Mean measurements (millimetres) and significance of differences)

—	S.D. Cross.		Corriedale.	
	Milk.	Rape.	Milk.	Rape.
S.D. Cross—				
Milk	39,123	SS	SS	SS
Rape	..	40,187	SS	SS
Corriedale—				
Milk	..	..	42,870	SS
Rape	..	..	..	42,275

SS = significant at 1 per cent. level; S = significant at 5 per cent. level; NS = not significant.

(*d*) *Length of Leg (F)*.—F is important primarily from a qualitative point of view. A short measurement is desirable as indicating a well-filled leg. In addition, F also shows a significant correlation with the total weight of muscle in the carcass (Part I). Since the length of T is reflected in this measurement, the discussion above on this latter measurement also applies, though to a lesser degree, since F takes into consideration the muscle and fat development in the crutch. The long F and T measurements characteristic of the Corriedale are largely responsible for the typical poorly-shaped leg joints found in this breed.

Because of this association, the order of breed differences is much the same as for T. It will be noted, however, that, while the difference between the T measurements of the light and the heavy S.D. Cross lambs is highly significant, there is no significant difference between the F measurements. This is probably due to increased muscle and fat development in the crutch with increased weight.

TABLE IXA.—INFLUENCE OF BREED AND WEIGHT ON LENGTH OF LEG (F)
(Mean measurements (millimetres) and significance of differences)

—	S.D. Cross.		Corriedale.		Romney × Corriedale.		S.E. of Mean.	Number in Group.
	Light.	Heavy.	Light.	Heavy.	Light.	Heavy.		
S.D. Cross—								
Light ..	230·22	NS	SS	SS	SS	SS	0·27	185
Heavy ..	..	230·77	SS	SS	SS	SS	0·29	157
Corriedale—								
Light ..	..	..	258·72	SS	SS	NS	1·15	97
Heavy ..	..	..	..	264·14	SS	SS	1·08	111
Romney × Corriedale—								
Light ..	..	..	..	..	244·89	SS	1·69	45
Heavy ..	..	..	..	..	..	255·59	2·76	17

SS = significant at 1 per cent. level; S = significant at 5 per cent. level; NS = not significant.

There is no difference in leg length between the S.D. Cross lambs fattened off their mothers and those fattened on rape. The rape-fattened Corriedales, however, are shorter in the leg than milk-fattened Corriedales.

The fact that there is no difference in T (Table VIIB) supports the suggestion that this improvement in leg length is due largely to the better development of muscle and fat in the crutch of the rape-fed lambs, a result in line with the greater response of late-developing tissues to improved nutrition. In these Corriedale lambs we have an example of a late-developing breed, critically retarded in growth, responding to subsequent good nutrition by increased development in a late-developing region.

TABLE IXB.—INFLUENCE OF FATTENING SYSTEM ON LEG LENGTH (F)
(Mean measurements (millimetres) and significance of differences)

—	S.D. Cross.		Corriedale.		S.E. of Mean.	Number in Group.
	Milk.	Rape.	Milk.	Rape.		
S.D. Cross—						
Milk	230·47	NS	SS	SS	0·64	342
Rape	..	227·83	SS	SS	1·26	87
Corriedale—						
Milk	..	..	261·62	SS	0·81	208
Rape	..	..	..	249·20	1·18	99

SS = significant at 1 per cent. level; S = significant at 5 per cent. level; NS = not significant.

(*e*) *Difference between Leg Length and Tibia + Tarsus Length (F — T)*.—Palsson(6) found this difference to show a strong negative correlation with the proportion of muscle to bone in lambs. This correlation did not hold in respect to a straight line of Canterbury lamb (Part I), (Table III).

A short F — T measurement was considered by Palsson to be important as indicating the required conformation of the leg. It is obvious, however, that a long T and a relatively short F will yield a low difference, but the type of joint resulting will have a poor conformation. For this reason the value of this measurement as a " shape index " for the leg is rather doubtful, a conclusion supported by our data.

Thus Table XA shows the results of a comparison of this measurement to be rather anomalous. The heavy S.D. Cross lambs have an F — T measure which is shorter than that of the light-weight lambs. The superior " leg " of the former group supports the requirement of a short F — T. Between the Corriedale weight groups, however, the difference is reversed, although the heavy lambs yield a much better leg joint, while no significant difference is shown between the two Romney × Corriedale groups, in which the heavy lambs are again superior in the " leg." Breed differences, however, are in the order of their superiority in so far as conformation of the leg is concerned, but it is considered that F alone provides a more satisfactory index of this character.

TABLE XA.—INFLUENCE OF BREED AND WEIGHT ON LEG LENGTH — TIBIA + TARSUS LENGTH (F — T)

(Mean measurements (millimetres) and significance of differences)

	S.D. Cross.		Corriedale.		Romney × Corriedale.		S.E. of Mean.	Number in Group.
	Light.	Heavy.	Light.	Heavy.	Light.	Heavy.		
S.D. Cross—								
Light ..	55·08	S	SS	SS	S	SS	0·88	185
Heavy ..	..	51·90	SS	SS	SS	SS	0·96	157
Corriedale—								
Light ..	..	..	65·29	S	S	NS	1·22	97
Heavy ..	..	..	..	68·76	SS	NS	1·14	111
Romney × Corriedale—								
Light ..	..	..	..	..	60·16	NS	1·79	45
Heavy ..	..	..	..	..	..	64·41	2·92	17

SS = significant at 1 per cent. level; S = significant at 5 per cent. level; NS = not significant.

A similar situation is apparent from the comparison of rape and milk lambs. Rape-fed lambs are shorter in this measurement than milk lambs. In the case of the S.D. Cross lambs this is due to differences in the T measurement only (there being no significant difference in F), but in the Corriedales the reverse is the case. This illustrates the point made previously, and adds weight to the suggestion that little importance should be attached to F — T measurements.

TABLE XB.—INFLUENCE OF FATTENING SYSTEM ON LEG LENGTH — TIBIA + TARSUS LENGTH (F — T)

(Mean measurements (millimetres) and significance of differences)

	S.D. Cross.		Corriedale.		S.E. of Mean.	Number in Group.
	Milk.	Rape.	Milk.	Rape.		
S.D. Cross—						
Milk	53·62	SS	SS	SS	0·62	342
Rape	..	48·10	SS	SS	1·23	87
Corriedale—						
Milk	..	..	67·14	SS	0·79	208
Rape	..	..	..	56·32	1·15	99

SS = significant at 1 per cent. level; S = significant at 5 per cent. level; NS = not significant.

(*f*) *Depth of Thorax (Th)*.—Depth of chest, as a measure of the relatively less valuable fore-end of the carcass, is an important index of conformation. In a fat-lamb carcass of superior quality this measurement must not be too large, and if we accept the S.D. Cross lambs as of the required standard the relative merits of the other crosses studied may be evaluated. In line with the findings of McMeekan(5) with pig carcasses, no correlation between thorax depth and carcass composition could be established (Part I).

Differences in chest depth between the various groups are not as marked as in other carcass measurements studied. S.D. Cross lambs show the smallest measurement and Corriedales the largest, with Romney × Corriedales in an intermediate position. This order is in line with the relative blockiness of form of these three types. As must be expected, heavier carcasses in each case show increased chest depth relative to light-weights.

TABLE XIA.—INFLUENCE OF BREED AND WEIGHT ON DEPTH OF THORAX (TH)
(Mean measurements (millimetres) and significance of differences)

—	S.D. Cross.		Corriedale.		Romney × Corriedale.		S.E. of Mean.	Number in Group.
	Light.	Heavy.	Light.	Heavy.	Light.	Heavy.		
S.D. Cross—								
Light ..	247·90	SS	S	SS	S	SS	1·14	185
Heavy ..	..	252·98	NS	SS	NS	SS	1·23	157
Corriedale—								
Light ..	..	..	251·80	SS	NS	SS	1·57	97
Heavy ..	..	..	..	260·70	SS	NS	1·46	111
Romney × Corriedale—								
Light ..	..	..	..	..	253·50	SS	2·30	45
Heavy ..	..	..	..	..	..	264·4	3·74	17

SS = significant at 1 per cent. level; S = significant at 5 per cent. level; NS = not significant.

No significant differences exist between the milk- and rape-fattened lambs within each breed group. As in the breed comparison above, the Corriedales are again deeper in the chest than the S.D. Cross lambs.

TABLE XIB.—INFLUENCE OF FEEDING SYSTEM ON DEPTH OF THORAX (TH)
(Mean measurements (millimetres) and significance of differences)

—	S.D. Cross.		Corriedale.		S.E. of Mean.	Number in Group.
	Milk.	Rape.	Milk.	Rape.		
S.D. Cross—						
Milk	250·26	NS	SS	SS	0·80	342
Rape	..	251·16	SS	SS	1·59	87
Corriedale—						
Milk	..	..	256·56	NS	1·03	208
Rape	..	..	..	257·46	1·49	99

SS = significant at 1 per cent. level; S = significant at 5 per cent. level; NS = not significant.

(*g*) *Length of Body (L)*.—Palsson(6) attributes differences in L to two causes—variation in the number of vertebræ, either thoracic or lumbar, and/or differences in the length of the vertebral bodies. While an increase in the number of lumbar vertebræ is desirable, an increase in the number in

the less valuable thoracic region is not. Since, as a whole, the most desirable conformation in sheep for meat purposes is of the short, blocky type, a long body does not generally confer any advantage.

Breed and weight will obviously influence this measurement. The S.D. Cross lambs are shorter than the other breeds. However, there is no difference between the Corriedales and the Romney × Corriedales. The heavy lambs within each breed group are longer than the light.

TABLE XIIA.—INFLUENCE OF BREED AND WEIGHT ON BODY LENGTH (L)
(Mean measurements (millimetres) and significance of differences)

—	S.D. Cross.		Corriedale.		Romney × Corriedale.		S.E. of Mean.	Number in Group.
	Light.	Heavy.	Light.	Heavy.	Light.	Heavy.		
S.D. Cross—								
Light ..	547·31	SS	SS	SS	SS	SS	1·28	185
Heavy ..	..	559·20	SS	SS	SS	SS	1·39	157
Corriedale—								
Light ..	..	..	572·69	SS	NS	SS	1·76	97
Heavy ..	..	..	..	587·40	SS	NS	1·65	111
Romney × Corriedale—								
Light ..	..	..	..	..	575·89	SS	2·59	45
Heavy ..	..	..	..	..	..	591·76	4·21	17

SS = significant at 1 per cent. level ; S = significant at 5 per cent. level ; NS = not significant.

The rape-fattened lambs in each group are shorter than those fattened off their mothers.

Between breeds, the Corriedales are longer than the comparable S.D. Cross lambs.

TABLE XIIB.—INFLUENCE OF FATTENING SYSTEM ON BODY LENGTH (L)
(Mean measurements (millimetres) and significance of differences)

—	S.D. Cross.		Corriedale.		S.E. of Mean.	Number in Group.
	Milk.	Rape.	Milk.	Rape.		
S.D. Cross—						
Milk	552·77	S	SS	SS	0·95	342
Rape	..	548·21	SS	SS	1·89	87
Corriedale—						
Milk	..	..	580·54	SS	1·23	208
Rape	..	..	..	561·11	1·77	99

SS = significant at 1 per cent. level S = significant at 5 per cent. level ; NS = not significant.

(*h*) *Length of Right Fore Cannon (M)*.—As would be expected from the studies of Hammond(2) and Palsson(6), breed differences in respect to the length of the cannon bones are marked. Only data concerning S.D. Cross and Corriedale lambs are available. All the differences within and between the breed groups are strongly significant. The light S.D. Cross lambs have by far the shortest cannons.

The cannon bone has mainly a quantitative importance. Various workers have found the length of this bone to show significant correlations with the total amount of bone in the carcass of meat animals (Hammond(2), Verges(7),

McMeekan(5)). The improved meat breeds are characterized by short, broad cannons, so that this type may be considered as generally desirable.

TABLE XIIIA.—INFLUENCE OF BREED AND WEIGHT ON CANNON BONE LENGTH (M)
(Mean measurements (millimetres) and significance of differences)

——	S.D. Cross.		Corriedale.		S.E. of Mean.	Number in Group.
	Light.	Heavy.	Light.	Heavy.		
S.D. Cross—						
Light	105·53	SS	SS	SS	0·51	78
Heavy	..	108·34	SS	SS	0·49	85
Corriedale—						
Light	..	..	116·17	SS	0·49	83
Heavy	..	..	..	119·54	0·47	90

SS = significant at 1 per cent. level; S = significant at 5 per cent. level: NS = not significant.

Though breed and weight thus influence cannon length to a marked degree, the system of fattening has exerted no measurable effect in S.D. Cross lambs. The cannon bone is one of the earliest-maturing bones, and in the S.D. Cross lambs the rapid rate of maturity has apparently allowed full development of the cannon bone before the lambs which had to be rape fattened suffered any setback.

The difference between the milk- and the rape-fattened Corriedales, however, is highly significant, the rape-fed lambs having shorter cannon bones. This result is somewhat unexpected, since it is not usual to find a difference due to nutrition in such an early-developing character as cannon bone length. The heavier carcass weight (2 lb.) of the milk-fattened Corriedales provides a possible explanation.

TABLE XIIIB.—INFLUENCE OF FATTENING SYSTEM ON CANNON BONE LENGTH (M)
(Mean measurements (millimetres) and significance of differences)

——	S.D. Cross.		Corriedale.		S.E. of Mean.	Number in Group.
	Milk.	Rape.	Milk.	Rape.		
S.D. Cross—						
Milk	106·8	NS	SS	SS	0·40	163
Rape	..	105·8	SS	SS	0·54	87
Corriedale—						
Milk	..	..	117·9	SS	0·39	173
Rape	..	..	..	116·0	0·51	99

SS = significant at 1 per cent. level; S = significant at 5 per cent. level; NS = not significant.

(*i*) *Weight of Right Fore Cannon.*—The value of the weight of one cannon bone for assessing the total weight of bone in the carcass has been demonstrated by Hammond(2) for sheep and McMeekan(5) for pigs. Breed and weight differences are more marked in respect to the weight of cannon bone than to the length. This is due to the fact that thickness of bone is a later-developing character than length(2, 5). Hammond, throughout all his work in this field, has demonstrated repeatedly the tendency for breeds to differ most in late-developing parts.

A VIRUS DISEASE OF HENBANE (*HYOSCYAMUS NIGER* L.) IN NEW ZEALAND

By C. H. PROCTER, Plant Diseases Division, Plant Research Bureau, Department of Scientific and Industrial Research

Summary

A virus disease caused considerable damage to henbane (*Hyoscyamus niger* L.) when this medicinal plant was grown in 1943 at Waiwhetu, Hutt Valley, New Zealand. Symptoms resemble in part those of *Hyoscyamus Virus II* and *Hyoscyamus Virus III* (Hamilton 1932), and in certain hosts symptoms are similar to those of *Solanum Virus II* (Potato Virus Y) (Smith, 1937; Dykstra, 1936, 1939).

Effective transmission was obtained both by leaf-rubbing and by the peach-aphid, *Myzus persicae* Sulz. Host range, symptoms in artificially-infected hosts, and identity of the virus are discussed. The physical properties of thermal death-point, dilution end-point, and longevity in vitro were determined.

INTRODUCTION

THE first reliable record of virus diseases occurring in henbane is that of Hamilton (1932), who observed the disease in commercial fields in Bedfordshire, England. Henbane is of recent introduction into New Zealand and was first grown under experimental conditions in 1942. Early in 1943 it was observed that from 10 per cent. to 20 per cent. of one-year-old plants showed root-rot, and that the foliage of these plants showed symptoms of possible virus infection. The disease was readily transmitted by artificial inoculations to *Nicotiana tabacum* L., and from this source material for experiments in New Zealand was derived.

SYMPTOMS

In the field, symptoms appear as severe stunting of growth with a puckering and slight mottling of the leaves. The mottling is light green, and distorted leaves are invariably present.

In the glasshouse, symptoms are of three general types: vein clearing, vein banding, and mottling of the leaves. Vein clearing occurs within nine days following inoculation as a primary symptom on the inoculated leaves and subsequent young growth. The loss of colour in and around the veins (Fig. 1, upper left) is very pronounced but is short lived, as a dark-green vein banding (Fig. 2) takes its place after six or seven days. The vein bands appear to be slightly raised above the surrounding tissue, may extend the whole length of the vein, and measure several millimetres across. Infected plants become greatly stunted, and after several weeks vein clearing and vein banding give place to a light- and dark-green mottle.

METHODS OF TRANSMISSION

(*a*) *Artificial Inoculation.*—This was obtained by leaf-rubbing with expressed juice from *Hyoscyamus* and infected Warne tobacco plants. The ease of transmission by this means is shown in Table 1.

(*b*) *Insect Transmission.*—Insect transmission, using the common peach-aphid, *Myzus persicae*, gave positive results (Table 1). The aphids were allowed to feed on infected plants for seven days and then transferred to healthy plants. These were enclosed in muslin cages. After feeding for a week on healthy plants, the aphids were killed by fumigation with nicotine sulphate. Other species of aphids were not tested as possible vectors.

HOST RANGE

Investigation of host range was limited to a number of plants of the Solanaceæ commonly used for identification of virus diseases. All inoculations were made by leaf-rubbing, using juice extracted from infected plants, generally Warne tobacco. Resistance and susceptibility of the hosts tested are shown in Table 1.

In most cases back inoculations to Warne tobacco from infected hosts or hosts suspected of infection were carried out to determine the possibility of a combination of two or more viruses. In all cases the original symptoms were reproduced thereby eliminating this possibility.

TABLE 1.—HOST RANGE OF THE VIRUS

Date of Inoculation.	Source of Inoculum.	Host inoculated.	Number of Plants inoculated.	Number of Plants infected.
21/4/43	*Hyoscyamus niger* ..	*Nicotiana tabacum* ..	6	6
17/8/43*	,, ..	,, ..	4	2
17/9/43*	,, ..	*Hyoscyamus niger* ..	6	6
20/5/43	*Nicotiana tabacum* ..	*N. tabacum*	6	6
21/7/43	,, ..	,, ...	6	6
6/8/43	,, ..	*N. rustica*	6	6
16/8/43	,, ..	*N. glutinosa*	4	4
23/8/43	,, ..	*N. glauca*	6	0
21/7/43	,, ..	*Lycopersicum esculentum*†	6	0
8/3/44	,, ..	,,	6	6
21/7/43	,, ..	*H. niger*	6	6
6/8/43	,, ..	*Atropa belladona* ..	6	0
23/8/43	,, ..	*Cyphomandra bltacea* ..	4	0
23/8/43	,, ..	*Petunia hybrida* ..	6	6
8/3/44	,, ..	*Solanum tuberosum* ..	6	6
15/3/44	,, ..	*Datura stramonium* ..	6	0
24/3/44	,, ..	*Solanum nigrum* ..	6	6
27/8/43	*N. rustica*	*N. tabacum*	3	3
28/3/44	*L. esculentum* ..	,, ...	4	4
28/3/44	*S. tuberosum* ..	,, ...	4	4
5/4/44	*S. nigrum*	,, ...	3	3

* Aphid transmission using *Myzus persicae*. † Back inoculations were not carried out in this instance. Control plants equal in number to those inoculated all remained healthy.

SYMPTOMS ON ARTIFICIALLY-INFECTED HOSTS

Nicotiana tabacum L. var. *Warne*

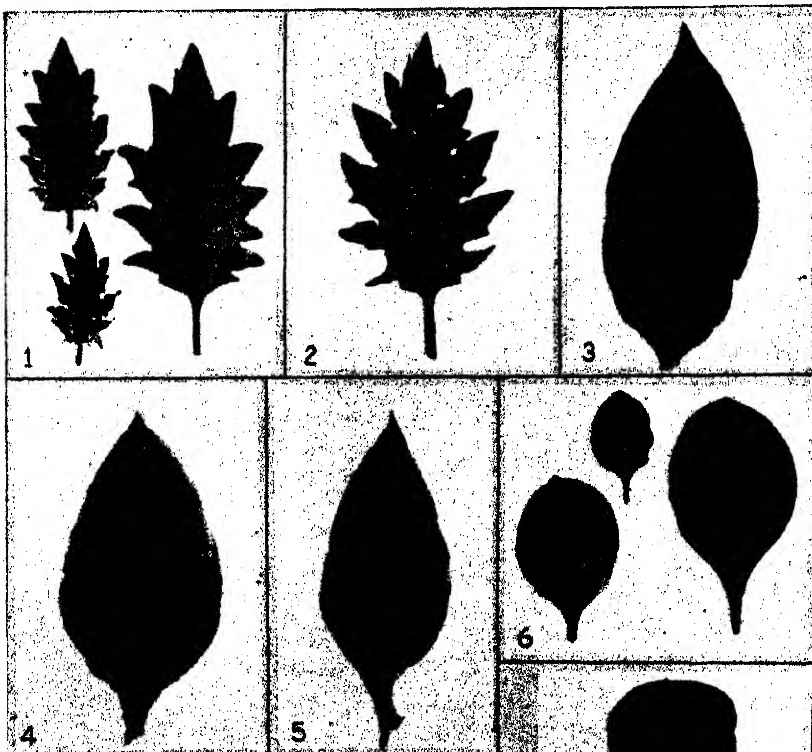
Three distinct symptoms occur—namely, primary vein clearing, secondary vein banding, and chlorotic mottling. The primary symptoms of vein clearing (Fig. 3) are similar to those in henbane. The secondary symptoms (Fig. 4) are also similar, except that in young leaves of old infected plants a pattern of short, narrow bands occurs on the small veins, giving the leaf a flecked appearance (Fig. 5). This latter symptom is not permanent and is followed by mottling of a chlorotic nature (yellow and light green), as compared with the light and dark green of henbane. Infected plants show very little retardation of growth.

Nicotiana rustica L.

Symptoms are less marked than in Warne tobacco, vein clearing being very faint and heavy vein banding absent. However, typical vein flecking and chlorotic mottling appear in later growth.

Petunia hybrida Vilm.

Vein-clearing symptoms (Fig. 6, left) occur on young inoculated leaves, and although vein banding does not develop, a slight to severe puckering occurs in some leaves. The growth of plants is not affected by infection and there is no evidence of " break " in flower colour.



FIGS. 1 TO 7.

Fig. 1.—Left: Vein-clearing symptoms on henbane. Right: Healthy leaf of henbane.

Fig. 2.—Vein-banding symptoms on henbane.

Fig. 3.—Vein-clearing symptoms on Warne tobacco leaf.

Fig. 4.—Vein banding of Warne tobacco.

Fig. 5.—Vein handling of flecking type on young leaf of old infected plant.

Fig. 6.—Left: Vein-clearing symptoms on Petunia leaves. Right: Healthy Petunia leaf.

Fig. 7.—Ring-spot symptoms on leaf of King Edward potato.

Nicotiana glutinosa L.

Twelve days after inoculation, mild vein-clearing symptoms appear, followed by yellow mottling and a crinkling or puckering of the leaves. After six to eight weeks the flecked type of vein banding occurs on lower leaves, and a mosaic mottling of dark-green areas becomes evident on leaves of auxiliary shoots. Streaks of dark green also develop on the stems of old infected plants. Flecking or " breaking " of the flower colour as recorded by Hamilton (1932) with *Hyoscyamus Virus III* did not occur.

Solanum tuberosum L. var. *King Edward*

Symptoms are markedly different from those described on the previous host-plants. Vein clearing and vein banding do not occur, but ring spots are formed on inoculated leaves (Fig. 7) and brown necrotic streaks appear on petioles and stems. The ring spots appear as dark-green rings 2–4 mm. in diameter with pale-green centres similar to the remainder of the leaf. The streaks on the petioles are from 1–3 mm. in length and often penetrate to the inner tissues. The stem streaks are longer, being 4–6 mm., and first appear immediately above the node of an infected leaf. Further streaks develop from the node upwards, and within four days the full length of the internode is stippled. Leaf-drop occurs within four days of infection, though the leaf may remain attached to the stem as if by a thread. This leaf-drop occurs first on the basal portions and gradually progresses up the stem, leaving a tuft of young leaves at the apex.

Lycopersicum esculentum Mill.

Vein-clearing and vein-banding symptoms are not perceptible in this host, but a bronze mottling appears on a number of leaflets twenty-five days after inoculation.

Solanum nigrum L.

No visible symptoms occur on this host, but when tobacco plants are inoculated with juice extracted from these plants typical symptoms are reproduced.

PHYSICAL PROPERTIES OF THE VIRUS

Longevity in Vitro

Plants were inoculated at twenty-four-hour intervals for ten days beginning 7th February, 1944, using inoculum extracted from recently-infected Warne tobacco plants. The extracted juice was stored in a test tube and held in an incubator at 23° C. Four leaves on each of four plants were inoculated by leaf-rubbing, and were examined daily for the first ten days and periodically for a further month.

Results showed that the virus remained virulent up to forty-eight but not seventy-two hours. The longevity of the virus therefore lies between these two periods.

Dilution End-point

The juice from recently-infected Warne tobacco plants was extracted and diluted with water. Groups of six tobacco plants were inoculated at different dilutions by the leaf-rubbing method. The trial was repeated, and results given in Table 2 indicate that the dilution end-point of the virus is between 1 in 10,000 and 1 in 100,000.

TABLE 2.—DILUTION END-POINT OF VIRUS

Date of Inoculation.	Source of Inoculum.	Strength of Inoculum.	Number of Plants Inoculated.	Number of Plants Infected.
29/2/44	Warne tobacco	1 in 1	6	6
29/2/44	"	1 in 10	6	6
29/2/44	"	1 in 100	6	6
29/2/44	"	1 in 1,000	6	3
29/2/44	"	1 in 10,000	6	1
29/2/44	"	1 in 100,000	6	0
29/2/44	"	1 in 1,000,000	6	0
30/3/44	"	1 in 1	6	6
30/3/44	"	1 in 1,000	6	5
30/3/44	"	1 in 10,000	6	2
30/3/44	"	1 in 100,000	6	0

Thermal Death-point

Determinations of the thermal death-point were carried out over a fairly wide range of temperatures with 5° C. difference between each treatment. Treatments consisted in heating two 1 ml. tubes of freshly-extracted juice from recently-infected Warne tobacco at each temperature for ten minutes. Immediately after completion of treatments, inoculations were carried out on Warne tobacco by the leaf-rubbing method. The trial was repeated, and results given in Table 3 show that the thermal death-point is between 60° C. and 65° C.

TABLE 3.—THERMAL DEATH-POINT OF VIRUS

Date of Inoculation.	Source of Inoculum.	Temperature, in Degrees Centigrade.	Number of Plants inoculated.	Number of Plants infected.
1/3/44	Warne tobacco	23 (air temp.) ..	6	6
1/3/44	"	45	6	6
1/3/44	"	50	6	6
1/3/44	"	55	6	6
1/3/44	"	60	6	1
1/3/44	"	65	6	0
1/3/44	"	70	6	0
31/3/44	"	22 (air temp.) ..	4	4
31/3/44	"	55	4	3
31/3/44	"	60	4	1
31/3/44	"	65	4	0

No work was undertaken to ascertain the filter-passing properties of the virus.

IDENTITY OF THE VIRUS

In many respects a number of symptoms of the virus dealt with in this paper closely resemble those of *Hyoscyamus Virus II* and *Hyoscyamus Virus III* (Hamilton, 1932). It agrees with *Hyoscyamus II* in puckered vein banding in henbane and the presence of fleck vein banding in tobacco, but differs in producing symptoms on tomato and potato. The New Zealand virus in some respects also agrees with *Hyoscyamus III* in vein clearing in henbane and tobacco, but differs in that it produces symptoms on potato and markedly different symptoms on tomato. From results obtained in host-range experiments it is clearly shown, especially in the case of tomato, that the virus is not a mixture of *Hyoscyamus II* and *Hyoscyamus III*, as separation of these two viruses occurs when the mixture is passed through tomato (Hamilton, 1932). It also differs in all respects from *Hyoscyamus I* as described by Hamilton.

Symptoms produced in some host-plants agree in part with those of *Solanum Virus II* (Potato Virus Y) (Smith, 1937; Dykstra, 1936, 1939). These resemblances are shown in vein clearing and vein banding in tobacco and henbane, and the formation of necrotic lesions and leaf-drop in potato. *Solanum Virus II*, however, differs in physical properties in symptoms on *Solanum nigrum*, tomato, petunia, and also in some of the symptoms on potato.

Thus it will be seen that the New Zealand virus cannot be identified with *Hyoscyamus Virus II*, *Hyoscyamus Virus III*, or *Solanum Virus II*, but since there are a number of close resemblances it is considered undesirable to specify the disease as a new virus until the relationships have been further investigated.

REFERENCES

DYKSTRA, T. P. (1936): *Phytopathology*, 26, 597–606.
——— (1939): *Ibid.*, 29, 40–67.
HAMILTON, MARION A. (1932): *Annals of Applied Biology*, 19, 550–567.
SMITH, K. M. (1937): "A Text-book of Plant Virus Diseases," 615 pp.

A VIRUS DISEASE OF FIG IN NEW ZEALAND

By LAI-YUNG LI, Plant Research Bureau, Department of Scientific and Industrial Research, and Lingnan University, Kwangtung, China; and C. H. PROCTER, Technical Assistant, Plant Diseases Division, Plant Research Bureau, Department of Scientific and Industrial Research

Summary

A virus disease of the fig, *Ficus carica* L., is recorded from many localities in New Zealand. Symptoms of the disease resemble those of *Ficus Virus I* Smith, 1937, and *Ficivir caricae* Condit and Horne, 1941. Symptoms showed both on leaf and fruit, and the virus may be responsible for the premature dropping of figs. The virus has been successfully transmitted by grafting and budding.

INTRODUCTION

THE fig, *Ficus carica* L., has long been in cultivation. From its original home somewhere in Eurasia it has now spread to many parts of the world. The first occurrence of virus disease of the fig is not known, but the first reliable record of a disease of virus nature is that of Condit and Horne (1933), who reported its presence in California. The disease was subsequently found in England; Porto Rico; Kwangtung, and Nanking, China; New South Wales, Australia (Pittman, 1935); and Texas, United States of America (Condit and Horne, 1941). In the San Joaquin Valley, California, in 1941, the senior author observed the widespread occurrence of this virus disease in fig plantations. In South China the virus is common on *Ficus carica* and possibly on other species of *Ficus* as well (Ho and Li, 1936).

The fig is not yet grown on a commercial scale in New Zealand, although it is commonly present in home gardens throughout the North Island from Wellington in the south to Maturoa Island, near Russell, in the north. Generally, only the second crop of fruits develop to maturity each year. The disease reported here was first observed on a tree in Wellington in 1942.

SYMPTOMS

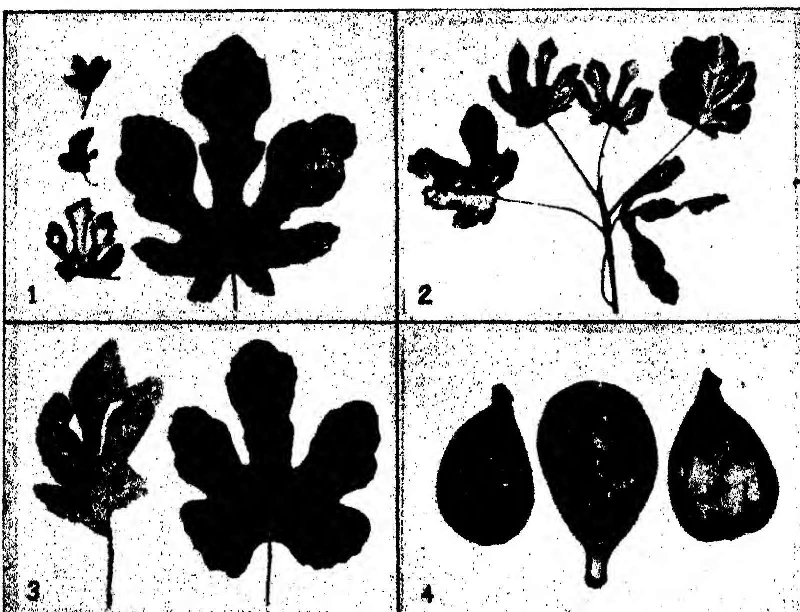
Symptoms of the disease appear both on foliage and on fruit. On foliage three general types of symptoms are recognized: a well-defined type, a diffused mottling, and a mosaic mottling. In the well-defined type of mottling, diseased areas appear as well-marked pale-green spots of various shapes and sizes which may coalesce to form larger spots, the borders of which are indefinite with a light yellow colour merging into the healthy green of surrounding normal tissue (Fig. 1, right). In the diffused type, symptoms appear as pale-green bands usually associated with the main veins (Fig. 1, left), in which case leaves are distorted and often very much reduced in size. It is not uncommon to find all leaves of a twig deformed (Fig. 2), and sometimes every leaf on a tree shows symptoms. A mosaic mottling of dark and light green also occurs, causing considerable malformation and distortion of leaves and veins (Fig. 3).

On the fruits the characteristic symptom is somewhat like the well-defined mottling on the foliage. The pale-yellow spots on the fruit are of various sizes and, as on the leaves, the diseased spots may merge together, forming a larger area (Fig. 4).

INCIDENCE

The disease is present in a number of apparently different varieties of fig in various parts of New Zealand. It was noted in 1942 in the following localities: Wellington, Auckland, Marlborough Sounds, Cambridge, Coromandel, and Hokianga.

Other species of *Ficus*—*Ficus retusa*, *F. repens*, *F. australis*, and *F. macrophylla*—grown here for ornamental purposes all showed suspected symptoms of virus attack, but the observations made on these species should not be taken as conclusive.



FIGS. 1 TO 5.

Fig. 1.—Disease symptoms on the foliage. Right: Well-defined type of mottling. Left: Diffuse mottling, showing malformation.

Fig. 2.—Twig showing virus symptoms on all leaves.

Fig. 3.—Diseases symptoms on foliage. Left: Mosaic mottling. Right: Healthy leaf.

Fig. 4.—Virus symptoms on fig fruits.

Fig. 5.—Disease symptoms on budding (lower branch) stock diseased.

EXPERIMENTAL TRANSMISSION

Experiments were conducted to transmit the virus from infected plants to healthy ones by several methods. The transmission was first attempted by hypodermic injection of juice from diseased leaves into young stems and leaf petioles of healthy plants. The attempt was a failure, as the injected, like the check, plants remained healthy. However, it is possible that the rapid extrusion of latex on puncturing prevented penetration of the active virus.

Grafting diseased budsticks on healthy stocks caused the stock to show disease symptoms in six weeks. Budding healthy buds on to diseased stocks permitted transmission of the virus after a similar period and produced characteristic symptoms on leaves of the buddlings (Fig. 5, lower branch). The checks for both budding and grafting experiments remained normal.

All cuttings taken from diseased trees produced diseased young plants when they rooted. The results of these virus transmission trials are included in Table I.

TABLE I.—TRANSMISSION OF FIG MOSAIC

Date.	Method of Transmission.	Number of Plants.	Number of Plants infected.
18/4/43	Cuttings	15	15
22/6/43	Injection	5	0
15/9/43	„	5	0
26/10/43	Grafting	3	3
28/10/43	Budding	5	4
11/11/43	„	4	2

NATURAL TRANSMISSION

The method by which transmission of the virus occurs in Nature is not known. However, a leaf-hopper, *Scolypopa australis* Walk., and a scale insect (*Lecanium* sp.) have been found on several diseased fig-trees in Auckland.

IMPORTANCE AND CONTROL

In general, the disease does not seem to have much effect on the growth of the tree. Diseased trees produce fruits which at times drop prematurely. Infected fruits are unsightly for market purposes. Condit and Horne (1933) reported that different species and varieties of fig showed different degrees of susceptibility to fig virus, and that some are immune or resistant. For the immediate future, practical control measures should consist of propagation—usually by cuttings—from healthy trees, and, later on, if culture becomes more important, selection and breeding for resistant and immune varieties should be attempted.

IDENTITY

Symptoms caused by the disease, both on foliage and on fruit, agree very closely with those of *Ficus Virus I* Smith, 1937, and a virus described by Condit and Horne, 1941.

ACKNOWLEDGMENTS

The authors take pleasure in thanking Dr. C. Parr, of Takapuna, and Mrs. Bidewell, Mount Albert, Auckland, who kindly supplied material for experiments, and to Miss M. J. Dahlberg for all the photographs illustrated in this paper.

REFERENCES

CONDIT, I. J., and W. T. HORNE (1933): A Mosaic of Fig in California. *Phytopathology*, *23*, 887–896.

——— (1941): Further notes on Fig Mosaic. *Ibid.*, *31*, 561–565.

——— (1943): Mosaic Spots of Fig Fruits. *Ibid.*, *33*, 719–723.

HO, W. T., and L. Y. LI (1936): Preliminary Notes on the Virus Diseases of some Economic Plants in Kwangtung, China. *Lingnan Sc. Jour.*, *15*, 69–70.

PITTMAN, H. A. (1935): Fig Leaf Mottle. *W. Australian Dept. Agric. Jour.*, *12*, 196.

SMITH, K. M. (1937): "A Text-book of Plant Virus Diseases," 615 pp.

A SENSITIVE STABLE VACUUM RELIEF VALVE FOR MILKING-MACHINES

By W. G. WHITTLESTON, Animal Research Station, Department of Agriculture, Wallaceville

Summary

The paper describes a vacuum relief valve which combines high sensitivity with stability. The valve is of the weighted type stabilized by a small oil damping mechanism.

INTRODUCTION

IN a previous paper(1) the writer described a method for testing the efficiency of vacuum relief valves of the type used on milking machinery, and the results obtained by using this test on a variety of commercial valves were given. An arbitrary standard by which to judge the performance of a valve was suggested—namely, the vacuum rise and drop must not exceed 1 in. of mercury when the air flow into the valve rises and falls between the limits 0·00 and 0·10 cubic feet per second of free air. This should be further qualified by specifying the opening vacuum to which the valve is set to be between 13 in. and 15 in. of mercury. It was noted that one make of weighted-type valve gave a performance somewhat better than the standard. However, when further valves of this type and make were tested no more were found to come within the requirements of the standard, the valve described being apparently an exceptionally good sample. It was therefore decided that a study should be made of valve design with a view to reaching the standard of performance set out above.

EXPERIMENTAL WORK

The first experiments were carried out on weighted valves in which the weight is suspended from a spherical or conical seat. It soon became evident that high sensitivity and stability are not compatible under field conditions, and an attempt was made to stabilize a sensitive valve by means of an oil damper. This attempt was successful, and, as the accompanying performance curve (Fig. 1) shows, the experimental valve reaches the standard requirements. All attempts to make the valve flutter by swinging the vacuum were unsuccessful.

A practical version of this experimental valve was designed, and several were constructed. The final form is shown in Figs. 2 and 3. This valve has now completed two years' trial under normal field conditions. The opening vacuum and sensitivity are found to remain constant, and, apart from filling the dash-pot once a season, the device requires no attention.

DESCRIPTION OF VALVE

The main body of the valve (*a*) is a brass casting designed to be sweated on to a standard 1¼ in. brass milk or air pipe. The seat (*b*) is made so that by the aid of a simple tool it can be removed readily and changed. The valve head is a bronze cone (*c*) with a cut across the top to facilitate its removal by means of a screwdriver. From the bottom of the valve head a large weight (*d*) is suspended, this latter having the small damping piston (*e*) fitted to it. This piston works in an oil-filled cylinder (*f*) supported by the

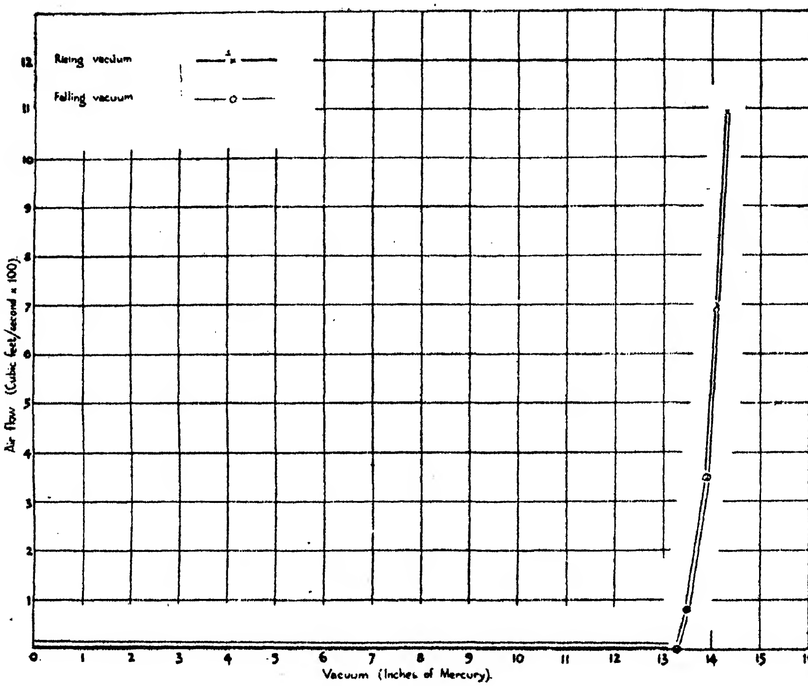


FIG. 1.—Performance curve of oil-damped relief valve.

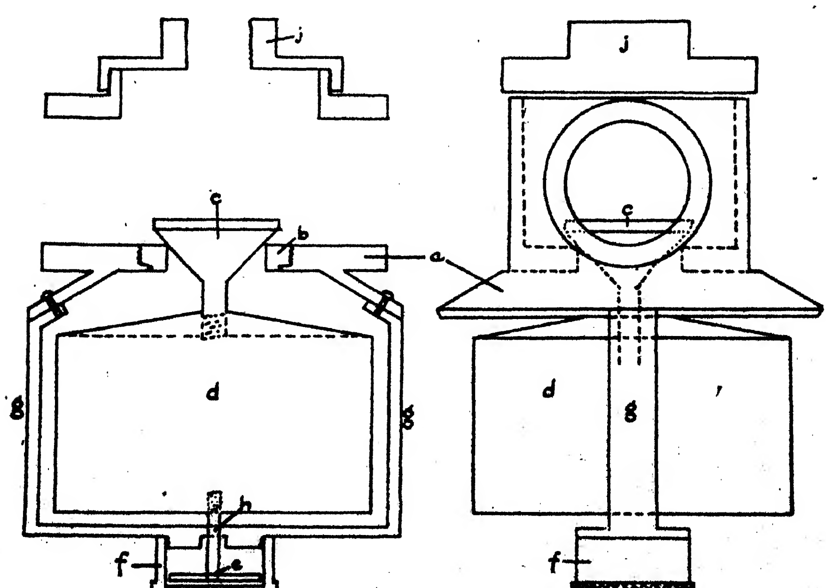


FIG. 2.—Sketch of valve and components. See text for explanation of letters.

members (g, g). The rod holding the piston, which clears the cylinder by about $\frac{1}{32}$ in., passes through a hole at (h) and so acts as a guide for the hanging weight. The presence of oil in (f) ensures that this bearing surface (the only possible source of friction in the valve) is well lubricated.

The valve is closed by the brass cap (j), which is provided with a threaded socket into which a vacuum gauge can be screwed.

THE PRACTICAL USE OF THE VALVE

Under normal field conditions there is no reason for frequent changing of the opening vacuum. However, should it be found desirable to make an alteration, this is done by changing the seat (b). A common but undesirable

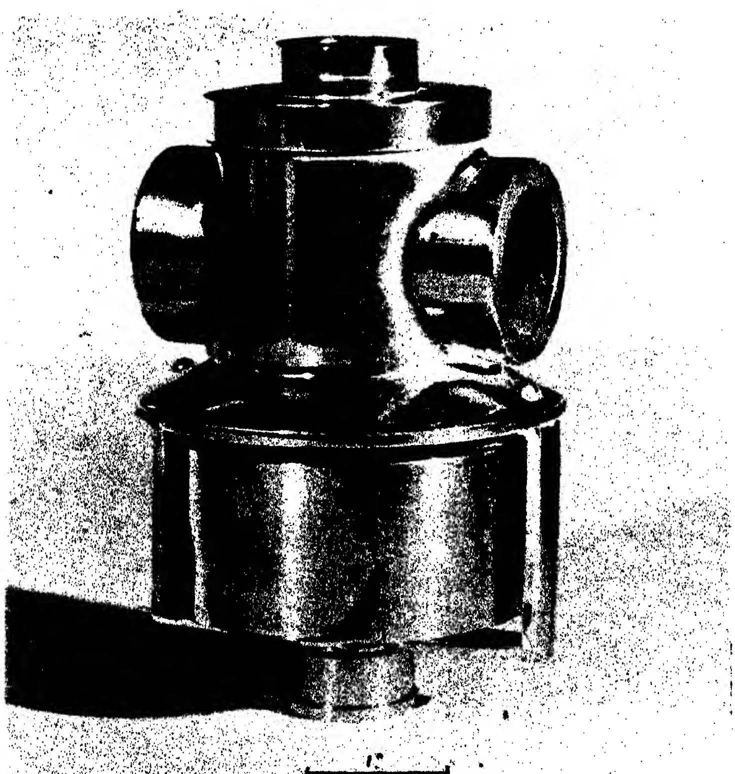


FIG. 3.—General appearance of valve.

practice is that of altering the vacuum in a milking-machine to suit circumstances. For instance, if the machine tends to milk slowly, it is often found that the farmer will attempt to improve the position by increasing the vacuum when, in fact, some other source of trouble should be rectified. The valve under discussion makes such practices at least difficult. It should be noted that in localities where there is a tendency for insects, pieces of straw, and the like to be drawn into the valve, a large gauze cover can be fitted without in any way reducing the sensitivity.

Small gauzes have been found to be undesirable because of the resistance offered to the incoming air.

Practical experience over two seasons with the valve has shown no difficulty in its use. The damper has been filled with ordinary rotary vacuum pump oil. This has been found to give adequate damping under the most difficult conditions. The valve has been found to be stable and sensitive over vacuums varying from 10 in. to 19 in. of mercury.

ACKNOWLEDGMENT

The writer wishes to acknowledge the assistance given by Mr. H. G. Sawtell, of this laboratory, in the construction of the experimental valves.

REFERENCE

(1) WHITTLESTON, W. G. (1948): Some Studies on the Properties of Milking-machine Relief Valves. *N.Z. Jour. Sci. & Tech.*, *24*, 272B–81B.

A RECORD OF *PANISCUS* SP. ATTACKING *PIERIS RAPAE* LARVÆ IN NEW ZEALAND

By B. B. GIVEN, Entomology Division, Plant Research Bureau, Nelson

DURING January of 1942 the writer found four *Pieris rapae* larvæ in a small block of cabbages at the Cawthron Institute, Nelson, each with a glossy black egg firmly attached to the dorsal surface on either the second or third segment. Of these eggs, one was dissected from the host for purposes of drawing and measurement, while the other three were allowed to develop.

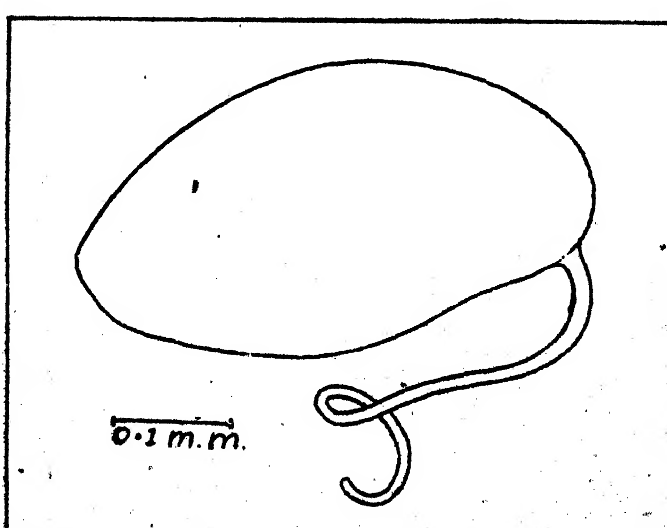
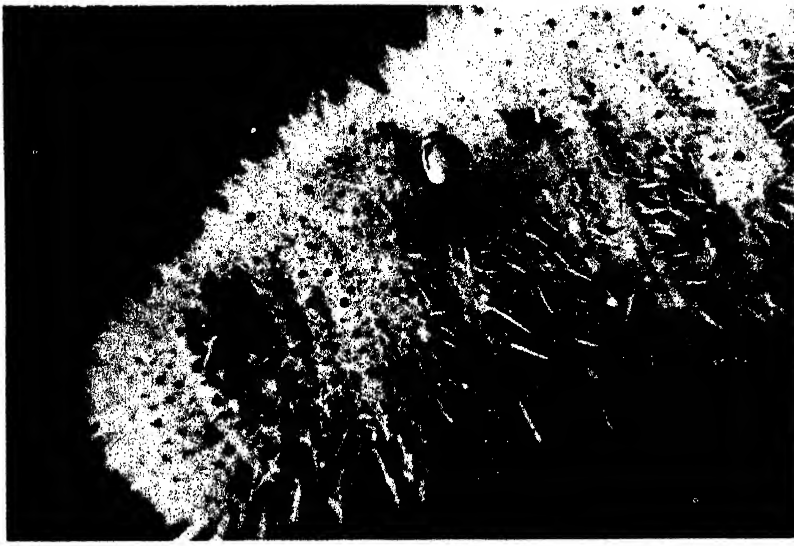


FIG. 1.—Egg of *Paniscus* sp. dissected from *Pieris* larva.



[Photo by Wm. C. Davies.

FIG. 2. *Paniscus* egg with larva emerging.

[Photo by Wm. C. Davies.

FIG. 3.—*Paniscus* first instar larva supported by egg-case anchored by pedicel, feeding on *Pieris* larva. Note cocoons of *Apanteles glomeratus* from same host.

The egg dissected from the host is shown in Fig. 1, and illustrates the typical structure of the *Paniscus* egg, with the coiled pedicel which so effectively grips the host tissue and supports the young larva. It was unfortunate that all eggs were deposited on larvæ previously parasitized by the braconid, *Apanteles glomeratus*, and although the *Paniscus* eggs hatched, none reached the second instar, due to the emergence of the *Apanteles* larvæ and the death of the host. Whether or not *Paniscus* can be successfully reared on *Pieris* larvæ is still not known, and no further attacks in the field have been noted.

[*Photo by Wm. C. Davies.*

FIG. 4.—*Pieris* larva with *Paniscus* egg attached, and with *Apanteles glomeratus* cocoons.

ACKNOWLEDGMENT

I am indebted to Mr. Wm. C. Davies, of the Cawthron Institute, for the photographs used in this account.

REFERENCE

CUSHMAN, R. A. (1926): "Some Types of Parasitism among the Ichneumonidæ." *Proc. Ent. Soc. Wash.*, *28*, *2*, 25–51.

REVIEWS

IMPERIAL BUREAU OF PLANT BREEDING AND GENETICS: PHOTOPERIODISM IN THE POTATO

Imperial Bureau of Plant Breeding and Genetics: Photoperiodism in the Potato, by C. M. Driver and J. G. Hawkes, School of Agriculture, Cambridge, England, December, 1943; 36 pp.; price, 2s. 6d.

Part I.—General (C. M. Driver)

Vegetative growth in the potato is greatly stimulated by long-day conditions. Flowering seems to be favoured by long days and moderate temperatures, and be greatly depressed by short days. Stolon growth is generally favoured by long warm days, such conditions giving long stolons and numerous lateral and branched ones. The conditions suitable for maximum tuber yields appear to be long days to stimulate vegetative growth, followed by short days to turn the plant activity towards efficient tuberization. Tuber shape is smoother and more uniform under short-day conditions; long days produce the largest tubers, but there is a greater range in size. Maturity is hastened by short days at normal temperatures. Optimum temperature for tuber growth lies between 60° F. and 65° F. A number of relationships between the carbohydrate/nitrogen ratio of the plant at different stages of development have been worked out. The reaction of the plant to photoperiodism is stated to be inherited.

Part II.—The Photoperiodic Reactions of some South American Potatoes (J. G. Hawkes)

The experiments were planned to investigate the periodicity of a collection of Peruvian potatoes. The results for tuber weight are in general agreement with those of the Russian and German workers on the South American potatoes. Stolon-production under short or long days is described for each species. The results for growth and maturity indicate that the clones under consideration take, on the average, about one and a half times as long to mature under long day as they do under short day. The height of the plants is, however, about two and a half times as great. Short days are shown to exert a depressing influence on flowering, although it is pointed out that flowering is extremely abundant in the high Andes under short-day conditions. This apparent anomaly is suggested to be due to the fact that flowering with the potato is not dependent on a photoperiodic mechanism, but rather on the quantity of light received. The potato is contrasted with other tropical plants (tobacco, soya bean) where the flowering is dependent on a photoperiodic response, and it is tentatively suggested that the photoperiodic mechanism applies only to the dominant method of reproduction. The potato reproduces almost entirely vegetatively and this is controlled by photoperiod.

D. C.

CO-ORDINATED TRIALS WITH PHENOTHIAZINE AGAINST NEMATODES IN LAMBS

Co-ordinated Trials with Phenothiazine against Nematodes in Lambs. Imperial Agricultural Bureaux Joint Publication No. 4; 56 pp.; 3s. 6d.

In view of the occurrence of certain discrepancies in the published reports on the use of phenothiazine as an anthelmintic and the fact that different criteria have been employed by different workers in testing its efficacy, the Agricultural Research Council of the United Kingdom decided to institute a series of co-ordinated trials at several centres. These trials were so planned as to give results capable of adequate statistical analysis in the hope that they would afford answers to certain specific questions.

In the course of these experiments phenothiazine has been tested in single doses against sheep nematodes in trials involving some 280 lambs at different centres in Great Britain using (*a*) lamb weights, (*b*) egg counts, and (*c*) worm counts, as criteria of

efficiency. Full details are given of methods used, and it is shown that egg- and worm-counting techniques are satisfactory. The results of these experiments have been given to the Executive Council of the Imperial Agricultural Bureaux for publication. Copies are available from the Imperial Agricultural Bureaux, Central Sales Branch, Agricultural Research Building, Penglais, Aberystwyth, Wales.

A NEW SERIES OF PLANT SCIENCE BOOKS

Edited by Frans Verdoon, and published by the Chronica Botanica Co. at Waltham, Mass., U.S.A., this series of books is already a valuable addition to up-to-date accounts of various branches of plant science. The format and general set-up is good, and the authors of repute in their subjects. Those that have come before us are—

Plants and Vitamins, by W. H. Schoffer. $4.75.
An Introduction to Pollen Analysis, by G. Erdtman. $5.
Plant Viruses and Virus Diseases (Second edition), by F. C. Bawden. $4.75.

These, while giving a review of the present state of the subjects, cater especially for the workers engaged in research on different aspects. All can be strongly recommended. With work so actively proceeding, none of course give a complete picture, and experts will find much to criticize as well as much to suggest where further advances may be made. The series is also procurable from Messrs. Angus and Robertson, Sydney.

H. H. A.

TABLE XIVA.—INFLUENCE OF BREED AND WEIGHT ON CANNON BONE WEIGHT
(Mean weights (grams) and significance of differences)

—	S.D. Cross.		Corriedale.		S.E. of Mean.	Number in Group.
	Light.	Heavy.	Light.	Heavy.		
S.D. Cross—						
Light	30·69	SS	SS	SS	0·374	78
Heavy	..	32·68	SS	SS	0·361	85
Corriedale—						
Light	..	..	36·21	SS	0·346	89
Heavy	..	..	..	39·08	0·346	99

SS = significant at 1 per cent. level; S = significant at 5 per cent. level; NS = not significant.

The cannon bones of the rape-fed lambs are lighter, suggesting that the setback in growth which necessitated rape fattening has affected the skeletal development in its later-developing character of thickness growth. The effect has been more marked upon the later-maturing Corriedale. Both these observations are in accord with the general principles governing the differential effect of nutrition(5).

TABLE XIVB.—INFLUENCE OF FATTENING SYSTEM ON CANNON WEIGHT
(Mean weights (grams) and significance of differences)

—	S.D. Cross.		Corriedale.		S.E. of Mean.	Number in Group.
	Milk.	Rape.	Milk.	Rape.		
S.D. Cross—						
Milk	31·73	SS	SS	SS	0·27	163
Rape	..	30·25	SS	SS	0·37	87
Corriedale—						
Milk	..	..	37·72	SS	0·25	188
Rape	..	..	..	35·56	0·35	99

SS = significant at 1 per cent. level; S = significant at 5 per cent. level; NS = not significant.

The most easily-measured index of bone thickness is the weight : length ratio. Table XV shows the average weight in grams per centimetre of the right fore cannon bone (based on the means).

TABLE XV

S.D. Cross—	
Light	29·08
Heavy	30·16
Corriedale—	
Light	31·17
Heavy	32·69

The difference between the S.D. Cross weight groups is not significant, but the heavy Corriedales have a higher ratio than the light Corriedales.

THE INFLUENCE OF SEX UPON CARCASS MEASUREMENTS

Sex differences in carcass measurements are shown in Table XVI. Wether lambs are wider in the gigots, longer in the leg bones (tibia + tarsus), deeper in the body (thorax depth), and better filled in the crutch (F — T). A small

difference in length of carcass in favour of the wether lambs is not significant, while no difference exists in leg length (F).

TABLE XVI.—INFLUENCE OF SEX UPON CARCASS MEASUREMENTS

(Mean measurements (millimetres) and significance of differences)

Carcass Measurement.	Number.		Means.		Level of Significance.
	Wethers.	Ewes.	Wether.	Ewe.	
G	243	186	222·8 ± 0·40	220·5 ± 0·46	SS
T	243	186	179·2 ± 0·49	174·9 ± 0·56	SS
T × G	243	186	39926	38565	SS
Th	243	186	253·5 ± 1·1	246·4 ± 1·3	SS
F − T	243	186	50·9 ± 0·51	54·6 ± 0·58	SS
Cannon weight	147	103	32·5 ± 0·24	29·35 ± 0·29	SS
Cannon length ..	147	103	107·8 ± 0·32	104·6 ± 0·39	SS

The stronger bone development of the wether lambs is further illustrated by the respective cannon weights and lengths, which are greater in the male sex. This result agrees with that of Hammond(2), who found that the wether approaches the ram in length growth of its bones, while both length and thickness growth of bone is inhibited in the ewe. On the other hand, the reverse appears true of pigs, with which Wallace(11) reports a longer femur and tibia-fibula (though shorter cannon) in the natural female than in the castrate male.

In respect to muscle, the advantage possessed by the wether in T and G result in a higher T × G measure, indicating better muscle development in the male lamb. With both stronger bone and better muscle development, fat deposition must be less in the wether than in the ewe. This is illustrated in Table XVII, obtained by applying the equations developed in Part I.

TABLE XVII.—INFLUENCE OF SEX ON CARCASS COMPOSITION

——	Percentage Bone.	Percentage Muscle.	Percentage Fat.
Wethers	12·6	51·3	33·6
Ewes	12·2	50·3	35·0

While no data appears to be available on relative fatness of the two sexes in sheep, it is of interest to note that this result is the reverse of that obtained by Wallace(11) for pigs, where the female was heavier in the bone, heavier in muscle, and lighter in fat development than comparable castrate males. Sex differences in cattle appear to follow those shown to exist in this study for sheep (Gramlich and Thalman(13)). Commenting on this situation, McMeekan(5) states, " It is possible that there is a species difference, not necessarily in the nature of the response to castration but in the degree of the response. It is clear, for example, that castration in either sex will increase the amount of fat in the body ; whether the increase will be sufficient to alter the order of the difference between the sexes may depend upon the differences in endocrine balance produced by removal of the sex organs which may vary with species. A complete understanding of the results of castration must await solution of the many fundamental problems concerning the function, behaviour, and interrelation of the glands of internal secretion."

Whatever the fundamental causes may be, it is clear that sex influences the quality of a fat-lamb carcass. While this is so, it will be observed that the differences between the ewe and wether are of small dimensions and are unlikely to be of major commercial importance. In view of the frequently-reported opinions as to the over-fatness of New Zealand prime export lambs, the possibility of still further improving quality through slaughter of uncastrated male lambs is worthy of investigation.

REFERENCE

(13) GRAMLICH, H. J., and THALMAN, R. R.: *Neb. Agr. Exptl. Sta. (Bull.) 252.*

MANUFACTURERS' TOBACCO WASTES: UTILIZATION IN AGRICULTURE

By H. O. ASKEW and R. T. J. BLICK, Cawthron Institute, Nelson, New Zealand

Summary

Tobacco wastes amounting to approximately 445 tons result after tobacco is manufactured in New Zealand and represent material of a potential value of £2,500 per annum as fertilizers. The value of the nicotine on extraction would be about £8,000. Processing of the wastes for nicotine would not seriously depreciate their value as fertilizers after removal of the nicotine.

INTRODUCTION

IN the preparation of tobacco-leaf for the manufacture of cigarettes and pipe tobaccos a considerable proportion of the original weight of the leaf appears as a waste product, known in the trade either as "shorts" or "stems." The former consists of pieces of cut leaf, sometimes containing cleanings from the machines, &c., and the latter consisting of the midrib or main vein of the leaf. Since the annual consumption of tobacco-leaf in New Zealand amounts to 8,000,000 lb., it would appear that several hundred thousands of pounds-weight of these materials should be available for possible manufacture into other products.

In the United States of America the possibilities of extracting oils, waxes, acids, cellulosic materials, &c., from the large quantities of wastes available there have been explored, but it is not considered that the quantities available in New Zealand justify exploration in these directions. Two avenues of usefulness suggest themselves for the New Zealand materials, (i) for inclusion in fertilizers or for use direct as fertilizers, and (ii) for the extraction of nicotine. This latter in the form of nicotine sulphate could be made available to the farming and horticultural community for use in drenches against internal parasites and sprays against pests of fruit and other crops.

EXPERIMENTAL

Six samples of different types of waste tobacco products have been obtained from the three largest companies operating in New Zealand.

Determinations were made of lime, magnesia, phosphoric acid, potash, and total nitrogen contents, and these are expressed in Table 1 as percentages on the dry-matter basis. In addition, the glucose, fructose, and sucrose contents have been determined. These were done to give as complete a picture as possible of the composition of these wastes, although it is not

considered that they have any significance in the estimation of the value of these materials for processing under New Zealand conditions. The nicotine content of the samples has also been determined.

TABLE I.—CHEMICAL COMPOSITION OF TOBACCO WASTES
(Expressed as percentage on dry-matter basis)

Company.	Type of Waste.	Soluble Ash.	Insoluble Ash.	Lime, CaO.	Magnesia, MgO.	Phosphoric Acid, P_2O_5.	Potash, K_2O.	Nitrogen, N.	Glucose.	Fructose.	Sucrose.
A	Flue-cured "stems"	16·57	0·29	3·47	1·35	0·96	5·50	1·66	8·59	0·54	0·24
A	Fire-cured "stems"	21·77	0·83	4·06	1·44	0·67	7·76	2·60	0·00	0·00	0·00
A	"Shorts"	14·34	2·09	4·27	1·12	0·65	2·77	2·52	10·53	0·00	0·30
B	"Stems"	17·98	0·41	3·62	1·17	0·85	5·43	1·88	5·43	0·00	0·24
C	"Waste"	16·69	7·20	5·96	1·40	0·49	1·71	2·71	0·00	0·00	0·00
C	"Shorts"	13·30	4·97	3·90	1·10	0·55	2·87	1·88	4·30	0·11	0·00

The data show that considerable variations in mineral composition are to be found in these wastes. Contamination by earthy and sandy materials is variable, and in some cases is so large that the amounts of lime, magnesia, &c., found in the samples will be greater than corresponds to those in the vegetable material; on the other hand, the nitrogen figure will be lower than in the absence of this earthy matter. Considerable variations in chemical composition between these samples are to be seen, especially in the potash content. The fire-cured stems contained 7·76 per cent. K_2O on the dry basis, but the "waste" of company C contained only 1·71 per cent. K_2O. On the other hand, this latter waste showed 2·71 per cent. total nitrogen, the highest figure found in this series of samples.

The glucose contents of these samples were in most cases low, the highest being 10·53 per cent. and the lowest nil. In every case fructose and sucrose were either very low (½ per cent. or less) or apparently absent.

USE AS FERTILIZERS

The data of Table I can be calculated to a ton basis and the several nutrients converted to the equivalent amounts of the usual fertilizer materials. Lime is calculated to limestone, magnesia to dolomite, phosphoric acid to superphosphate, potash to sulphate of potash, and nitrogen to sulphate of ammonia. Table II gives the monetary values of the samples.

TABLE II.—VALUE, PER TON, OF TOBACCO WASTES AS FERTILIZERS

Company.	Type of Waste.	Value, Dry Basis.	Value, Commercial Basis (at Manufacturers).
		£ s. d.	£ s. d.
A	Flue-cured "stems"	6 10 6	6 0 0
A	Fire-cured "stems"	9 5 0	7 19 0
A	"Shorts"	5 12 0	4 16 0
B	"Stems"	6 12 9	5 10 0
C	"Waste"	4 18 3	4 4 0
C	"Shorts"	3 14 9	3 4 0

NOTE.—The following values per ton have been used in the above calculations: limestone, £1; dolomite, £4; superphosphate, £6 10s.; sulphate of potash, £35; and sulphate of ammonia, £25.

Under ordinary conditions these wastes would contain probably about 15 per cent. of moisture, so that the commercial value would be about one-seventh less than the dry-basis value. This commercial value is given in the right-hand column of Table II.

Complete data are not at hand for the total quantities of these wastes available annually. Some of the companies have indicated the amounts they have for disposal, but also stated that they already have outlets for part of the material. The following are the calculated values of the annual production of these wastes, the figure for company C being an estimate:—

Company.	Tons.	Value. £
A	318	1,938
B	57	313
C	70	300
Totals	445	2,551

A prospective value of £2,551 is therefore found for the wastes available annually from the three largest companies operating in New Zealand.

Three of the samples of "shorts" carry appreciable percentages of potash, and all the samples have useful percentages of nitrogen. The whole of the potash can be considered to be in a readily-available state. On the other hand, the nitrogen would become available slowly and thus should, perhaps, be rated at a lower value than the equivalent amount of sulphate of ammonia, to which form the nitrogen figures have been calculated above. The material of the high-value samples would appear to be worth grinding for use as fertilizers. These samples would be valuable not only as fertilizers used direct, but also as conditioning agents in mixed fertilizers. Moreover, the organic constituents, on which no monetary value has been placed, have some value as soil-improvers.

RECOVERY OF NICOTINE

Besides their value as fertilizers, these residues have a potential value as a source of nicotine for the preparation of nicotine sulphate. In Table III the percentages of nicotine on the dry basis and the value of the nicotine per ton of material both on the dry basis and on the basis of a content of approximately 15 per cent. of moisture are set out.

TABLE III.—NICOTINE IN TOBACCO WASTES

Company.	Type of Waste.	Nicotine. per Cent.	Value, Dry Basis, per Ton.	Value, Commercial Basis, per Ton.
			£	£
A	Flue-cured "stems"	0·92	15·4	14·2
A	Fire-cured "stems"	1·83	30·7	26·3
A	"Shorts"	1·99	33·4	28·6
B	"Stems"	0·66	11·1	9·5
C	"Waste"	2·00	33·6	28·8
C	"Shorts"	1·43	24·0	20·6

In arriving at the above data, pure nicotine has been valued at 15s. per pound. This is, of course, approximately the wholesale value of the nicotine after processing. Just what price could be paid for these wastes for nicotine-extraction purposes cannot be stated definitely, but it would probably be not more than about £8 per ton. This is, however, at least as much as it is valued at for fertilizer purposes.

Using the same data for quantities of wastes as in the previous calculation of total value as fertilizers, the annual values of the nicotine extractable from them would be (assuming complete extraction of the nicotine):—

	£
Company A	5,528
Company B	543
Company C	2,016
Total	8,087

Recovery of this £8,000 worth of nicotine would go far towards satisfying New Zealand's annual requirement for this chemical. In a process which has been developed and is awaiting trial on a small commercial scale, the nicotine would be made available in the form of a 40 per cent. solution of nicotine as sulphate.

DISCUSSION

Owing to the widespread occurrence of bacterial and virus diseases in all tobacco-growing countries of the world there may be some misgivings in the use of tobacco wastes for fertilizer purposes. The wastes could, however, be sterilized either by dry heat or by the use of superheated steam. Either method of sterilizing would possibly reduce the nitrogen content slightly, but the mineral constituents would not be affected. Whether the materials could bear this extra cost of preparation for sale is problematical. On the other hand, the residue freed from nicotine should not act as a carrier of disease, because in the final stage of the extraction process it is dried by superheated steam and should therefore be sterilized. It would also be in a reasonably fine state of division suitable for use as a fertilizer. Moreover, none of the potash, lime, or magnesia is removed: indeed, the lime content is increased owing to the addition of hydrated lime to set free the nicotine before extraction. Owing to the action of the lime there will, however, be some reduction of readily-available nitrogen, and the total nitrogen content will be reduced by removal of the nicotine. Sale of the extracted residue may be expected to help offset part of the cost of production of the nicotine.

A NOTE ON THE AVAILABILITY TO SHEEP OF PHOSPHORUS IN THE FORM OF ACID SODIUM PYROPHOSPHATE

By L. W. N. FITCH and I. G. McINTOSH, Animal Research Station, Wallaceville, Department of Agriculture

Summary

Four hours after the oral administration of 2·0 g. of phosphorus in the form of acid sodium pyrophosphate the blood inorganic phosphorus of a group of sheep was significantly raised. The effect was comparable with that obtained when a similar amount of phosphorus in the form of sodium dihydrogen phosphate was given.

INTRODUCTION

IN the course of experiments designed to test the value of phosphatic licks in the prevention of "bow-leg" in sheep it was considered desirable to administer phosphorus in a relatively pure form. Owing to wartime dislocation of transport, supplies of sodium orthophosphate or other salts in which the phosphorus is known to be readily assimilable by ruminants could not be obtained. We were able, however, to obtain adequate amounts of sodium pyrophosphate for experimental work, but no record of the availability to stock of phosphorus in this form could be found. In view of the relative stability of pyrophosphate in vitro* it was necessary to test the effect on blood phosphorus of feeding it to sheep before using it in field trials.

EXPERIMENTAL

Experiment A

In a preliminary trial two groups of five Romney hoggets (age ten months) were employed, the first receiving pyrophosphate and the second being untreated controls. The sheep were grazed, being brought in about 8.15 a.m. and bled at once for phosphorus determination†. They were handled with care to avoid excitation, and the uniformity of the pretreatment figures indicates their reliability as a basis for assessing the effects of the treatment to which they were subjected. Initially the pyrophosphate was given as a drench, but from 27th July, 1943, was given dry in half-ounce gelatin capsules. This was a much simpler method of administration. As morning blood samples from sheep dosed with four or sixteen grams of pyrophosphate twenty-four hours previously, showed no increase in phosphorus content, a series of samples were later collected at shorter intervals, up to six hours after treatment. The results indicated that the treatment had raised the blood phosphorus, and it was decided to check this finding on larger groups of sheep. The results of the preliminary trial are tabulated in Table I. Sheep Nos. 84 in group I and 65 in group II had persistently low blood

* 0·5 per cent. solutions of acid sodium pyrophosphate, with and without the addition of 0·1 per cent. pepsin (final pH adjusted to 2·0) or 0·1 per cent. trypsin (final pH adjusted to 7·5), were incubated for three days at 37° C. No conversion to orthophosphate could be detected in any of the solutions during this period.

† The method of Briggs (1922) was employed in which phosphorus in the form of orthophosphate but not as pyrophosphate is determined, hence the values given do not include any pyrophosphate that may have been present in the blood. No attempt was made to determine whether phosphorus was present in the blood in this form.

TABLE I.—PRELIMINARY TRIAL (EXPERIMENT A): BLOOD PHOSPHORUS, IN MILLIGRAMS PER CENT.

Date / Time bled	13/7. 8.30.	14/7. 8.30.	15/7. 8.30.	19/7. 8.30.	20/7. 8.30.	21/7. 8.30.	22/7. 8.30.	23/7. 8.30.	26/7. 8.30.	27/7. 8.30.	28/7. 8.30.	29/7. 8.30.	29/7. 1 p.m.	30/7. 8.30.	30/7. 11a.m.	30/7. 1 p.m.	2/8. 9 a.m.	2/8. 1 p.m.	2/8. 3 p.m.
Dose, in Grams*, of pyrophosphate	..	..	..	..	4	4	4	4	16	16	16	16	..	16	..	..	16	..	..
Group I.—Received Pyrophosphate																			
Sheep—																			
50	4·2	4·6	4·7	4·3	3·9	5·3	4·3	4·6	4·4	5·0	4·8	3·6	6·0	4·3	4·7	5·6	4·3	5·0	6·0
62	4·8	4·5	4·3	4·0	4·5	5·0	4·7	5·0	5·0	5·2	6·0	5·9	6·9	5·6	6·4	6·9	4·8	6·2	6·4
64	5·6	5·3	5·6	5·3	5·3	5·4	5·1	5·2	5·3	5·4	4·6	5·6	7·5	6·4	7·2	8·2	4·3	6·1	6·4
84†	1·3	1·6	1·6	1·6	1·6	1·8	2·2	1·3	1·2	3·4	11·2	..	..	..	..	..	..	..	..
86	4·1	5·0	5·0	4·3	5·0	5·3	5·3	5·0	5·1	3·8	4·5	4·0	4·3	4·0	4·3	3·9	3·4	3·8	3·8
Average of four	4·7	4·9	4·9	4·5	4·7	5·3	4·9	5·0	5·0	4·9	5·0	4·8	6·2	5·1	5·7	6·2	4·2	5·3	5·7
Group II.—Untreated Controls																			
Sheep—																			
46	4·6	4·9	4·7	5·3	5·3	5·0	5·0	5·3	4·6	5·4	5·0	5·3	5·8	5·4	5·6	4·8	5·0	4·8	4·7
47	4·7	4·7	4·8	5·0	5·1	5·5	6·0	5·6	4·3	6·0	5·4	5·7	5·5	5·3	5·3	4·2	4·9	4·7	4·5
65†	2·8	2·8	2·8	2·6	2·7	2·8	2·9	2·4	2·6	2·6	2·7	2·1	1·9	1·8	2·2	1·9	1·9	1·6	2·0
66	4·5	4·3	4·4	4·2	4·3	4·5	4·1	4·3	4·7	4·7	4·7	4·3	4·1	3·9	3·7	3·8	4·5	3·9	3·8
71	4·7	5·0	4·2	4·1	3·7	4·6	4·3	4·3	5·2	6·2	6·0	5·0	5·0	5·1	5·1	4·7	5·6	5·8	5·3
Average of four	4·6	4·7	4·5	4·7	4·6	4·9	4·9	4·9	4·7	5·6	5·3	5·1	5·1	4·9	4·9	4·4	5·0	4·8	4·6

* Sheep were drenched as soon as the bleeding of both groups was concluded. † Excluded from average (see text).

phosphorus levels. No. 84 died during the course of the trial, and to facilitate comparison of the groups both of these animals are eliminated from the averages. Neither showed any signs of illness before 28th July, 1943, when No. 84 was very depressed when brought in at 8.15 a.m. It was bled, but not drenched on this occasion. At 2.30 p.m. it was unable to stand, so a final blood sample was collected, and the animal was killed. Autopsy revealed acute abomasitis with extensive ulceration of the mucosa.

Experiment B

Two groups of ten Romney hoggets were used, each group including two of the treated animals from the previous experiment. Each group received at suitable intervals two treatments: acid sodium pyrophosphate 8 grams, and sodium dihydrogen orthophosphate 10 grams. Both treatments contributed approximately 2 grams of phosphorus per head. As previously, the sheep were bled in the mornings (approximately 8.30 a.m.) and drenched after the completion of the bleeding. On 4th August, 1943, group I received pyrophosphate, while group II were left as untreated controls. They were all bled at 1.0 p.m., four hours after treatment, and the following morning group II received orthophosphate, group I not being treated. On the third day further blood samples were collected for determination of phosphorus, and the sheep were then left at pasture until 9th August, 1943. Commencing 9th August, 1943, the foregoing procedure was repeated, except that the treatment of each group was reversed. The individual results are given in Table II and the group averages are graphed in Fig. 1. Table II includes a few observations made on the blood phosphorus content of group II two hours after receiving sodium dihydrogen orthophosphate.

RESULTS

The results clearly demonstrate that dosing sheep with 2 grams of phosphorus in the form of pyrophosphate is followed by a fairly rapid rise in blood phosphorus. The effect appears to be of a transient nature, as blood phosphorus is usually restored to normal in twenty-four hours. For comparison the response of the two groups to either treatment may be pooled and compared with the average change in blood phosphorus of both groups on the days when they represented the untreated controls at the commencement of the two experimental sub-periods (Experiment B, Table III). It will be seen that four hours after treatment with pyrophosphate the blood phosphorus was raised $1{\cdot}09 \pm 0{\cdot}12$ mg. per cent. compared with $0{\cdot}76 \pm 0{\cdot}09$ mg. per cent. after receiving orthophosphate. The average blood phosphorus elevation of both groups between 9 a.m. and 1 p.m., when untreated, was negligible.

DISCUSSION

The conditions under which it is proposed to employ pyrophosphate prophylactically are suggestive of phosphorus deficiency, and it is recognized that under such conditions sheep would probably react differently from normal animals as used in these experiments. We believe, however, that

TABLE II.—BLOOD PHOSPHORUS, IN MILLIGRAMS PER CENT., UNTREATED AND AFTER RECEIVING ORTHOPHOSPHATE AND PYROPHOSPHATE

Group I.			Sheep Number.											
Date.	Time bled.	Treatment (9 a.m.).	50.	62.	46.	66.	68.	69.	70.	90.	92.	95.	Group Average.	Average Elevation.
4/8/43	8.30 a.m.	Pyrophos.	3·9	5·0	4·7	3·9	5·0	3·8	4·6	5·2	4·5	5·6	4·62	1·13
"	1 p.m.	Nil	4·5	6·9	5·6	5·0	6·2	4·9	6·9	6·4	5·5	5·6	5·75	
5/8/43	8.30 a.m.	Nil	4·5	5·3	5·5	4·3	5·3	4·0	5·0	5·8	4·8	5·3	4·98	−0·22
"	1 p.m.	Nil	4·5	5·3	5·4	4·1	4·9	3·8	4·7	5·3	4·0	5·6	4·76	
6/8/43	8.30 a.m.	Nil	4·3	4·3	4·5	3·9	3·9	3·0	4·2	4·6	3·9	4·9	4·15	..
9/8/43	8.30 a.m.	Nil	3·8	4·5	4·7	4·2	4·8	3·5	3·9	5·0	3·6	3·9	4·19	−0·02
"	1 p.m.	Nil	4·3	4·0	4·5	3·9	5·1	3·1	4·7	4·0	3·3	4·3	4·17	
10/8/43	8.30 a.m.	Orthophos.	5·0	5·0	4·7	4·5	4·7	3·0	4·7	5·3	3·6	4·3	4·48	0·80
"	1 p.m.	Nil	5·6	5·3	5·3	4·7	6·0	3·8	5·6	6·2	4·7	5·6	5·28	
11/8/43	8.30 a.m.	Nil	5·6	5·1	4·5	3·8	5·3	3·2	5·0	5·6	4·3	5·3	4·77	0·04
"	1 p.m.	Nil	4·7	4·7	4·5	4·0	5·6	3·5	5·8	6·0	4·0	5·3	4·81	

Group II.			Sheep Number.											
Date.	Time bled.	Treatment (9 a.m.).	47.	64.	71.	73.	78.	80.	82.	83.	85.	86.	Group Average.	Average Elevation.
4/8/43	8.30 a.m.	Nil	5·3	4·6	5·3	3·0	4·3	5·2	5·3	5·6	5·0	3·6	4·72	0·19
"	1 p.m.	Nil	4·5	5·0	6·0	3·1	5·0	5·3	5·1	6·1	5·5	3·5	4·91	
5/8/43	8.30 a.m.	Orthophos.	4·7	4·6	5·3	3·2	4·7	5·1	5·3	5·3	5·5	3·6	4·73	0·71
"	11 a.m.	Nil	5·3	..	6·4	..	5·6	..	..	..	6·6	3·9	5·56	
"	1 p.m.	Nil	6·0	6·0	5·3	3·8	5·5	5·2	6·0	6·2	6·4	4·0	5·44	
6/8/43	8.30 a.m.	Nil	5·0	4·9	6·0	2·9	4·2	4·7	5·6	5·1	4·5	3·0	4·59	..
9/8/43	8.30 a.m.	Pyrophos.	4·5	4·6	4·1	2·9	3·9	4·3	4·5	5·3	4·7	2·4	4·12	1·05
"	1 p.m.	Nil	5·5	6·0	5·6	3·5	4·4	5·2	5·6	6·0	6·7	3·2	5·17	
10/8/43	8.30 a.m.	Nil	6·0	5·1	2·3	3·2	4·7	4·7	5·3	5·6	5·6	3·9	4·64	0·16
"	1 p.m.	Nil	5·3	5·3	5·6	2·9	4·6	4·5	4·7	5·6	5·6	3·9	4·80	
11/8/43	8.30 a.m.	Nil	6·0	5·3	6·0	3·3	4·5	4·5	5·3	5·6	5·6	3·8	4·99	0·01
"	1 p.m.	Nil	6·0	4·7	5·6	3·3	4·5	5·3	5·1	5·6	6·0	3·9	5·00	

the response to pyrophosphate would probably be accentuated, and hence that our results would apply with equal or greater force under conditions of sub-optimal phosphorus intake.

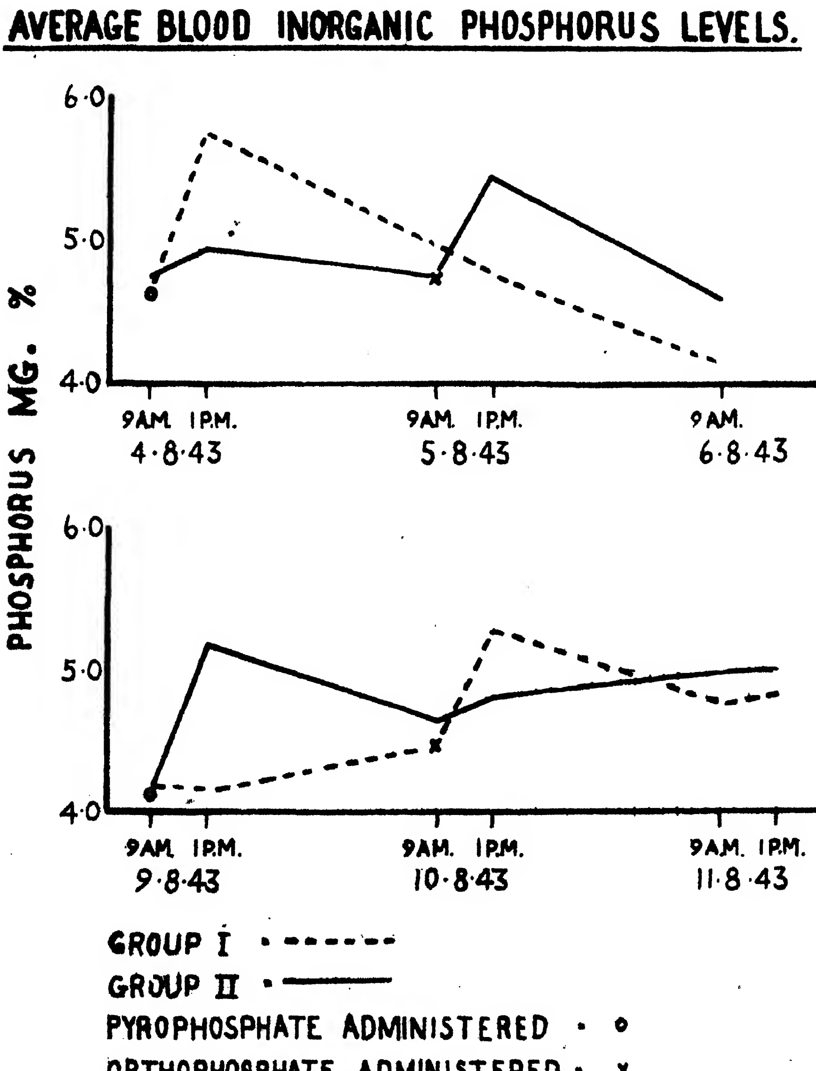


FIG. 1.—Average blood inorganic phosphorus levels.

The use of pyrophosphate is, of course, purely an experimental procedure, and it is not proposed that it should supplant more conventional sources of phosphorus in the prevention of phosphorus-deficiency diseases.

TABLE III.—ELEVATION OF BLOOD PHOSPHORUS OF INDIVIDUAL SHEEP BETWEEN 9 A.M. AND 1 P.M., UNTREATED, AND AFTER RECEIVING ORTHOPHOSPHATE AND PYROPHOSPHATE (ELEVATION EXPRESSED IN MILLIGRAMS PER CENT.)

Group and Sheep No.	No Treatment.		Orthophosphate.		Pyrophosphate.	
	Date.	Rise in Phosphate	Date.	Rise in Phosphate.	Date.	Rise in Phosphate.
Group I—						
50	9/8/43	0·5	10/8/43	0·6	4/8/43	0·6
62	"	−0·5	"	0·3	"	1·9
46	"	−0·2	"	0·6	"	0·9
66	"	−0·3	"	0·2	"	1·1
68	"	0·3	"	1·3	"	1·2
69	"	−0·4	"	0·8	"	1·1
70	"	0·8	"	0·9	"	2·3
90	"	−0·5	"	0·9	"	1·2
92	"	−0·3	"	1·1	"	1·0
95	"	0·4	"	1·3	"	0
Group II—						
47	4/8/43	−0·8	5/8/43	1·3	9/8/43	1·0
64	"	0·4	"	1·4	"	1·4
71	"	0·7	"	0	"	1·5
73	"	0·1	"	0·6	"	0·6
78	"	0·7	"	0·8	"	0·5
80	"	0·1	"	0·1	"	0·9
82	"	−0·2	"	0·7	"	1·1
83	"	0·5	"	0·9	"	0·7
85	"	0·5	"	0·9	"	2·0
86	"	−0·1	"	0·4	"	0·8
Average ..	..	0·08 ± 0·11	..	0·76 ± 0·09	..	1·09 ± 0·12
Comparison with untreated animals—						
Value of "T"	..	..	..	4·786	..	6·242
Significance ..	..	..	..	H.S.	..	H.S.

ACKNOWLEDGMENT

We are indebted to Miss C. Franz and Miss C. Murphy for much technical assistance.

REFERENCE

BRIGGS, A. P. (1922): *J. Biol. Chem.*, *53*, 13.

THE NEW ZEALAND

JOURNAL OF SCIENCE AND TECHNOLOGY

Editor: D. Cairns, M.Sc., Department of Scientific and Industrial Research, Wellington

VOL. 26, SEC. A | OCTOBER, 1944 | NUMBER 3

CANTERBURY LAMB

By D. E. WALKER and C. P. McMEEKAN, Animal Research Station, Department of Agriculture, Ruakura, Hamilton

[Received for publication, 16th June, 1944]

PART III. GROWTH AND CARCASS QUALITY OF FAT LAMBS OF DIFFERENT BREEDS UNDER "IDENTICAL" FIELD CONDITIONS

Summary

(1) Growth rate and carcass data on four groups of lambs raised under "identical" field conditions to measure normal variability have been reported.

(2) Considerable variability within each group in important carcass characters has been demonstrated. This is such that, when the factor or treatment under study is likely to be responsible for 20 per cent. or more of the total variance, sixteen animals provided an adequate number to permit differences in the more important carcass characteristics to show up to a significant degree.

(3) Comparisons of growth curves have been made which demonstrate the controlling influence of this variable upon fat-lamb quality. Growth curves for fat lambs raised under pasture conditions in New Zealand have been constructed.

(4) Comparison of the carcass quality of Corriedales, Border Leicester × Corriedale, Southdown × Corriedale, and Southdown × Romney fat lambs at nine months of age have been made, and the outstanding superiority of Down Cross lambs measured.

(5) A general survey of the carcass quality of the main breeds and crosses of New Zealand fat lamb and of the relative influence of breed, weight, age, fattening system, growth rate, and sex has been presented.

INTRODUCTION

It is well known that differences in nutrition cause differences in growth and development. The fact that animals ostensibly on the same plane of nutrition may grow and develop differently is also recognized in general terms. Since this latter situation is one which frequently characterizes stock under field conditions, it is important that the normal variance resulting from it and associated environmental influences should be accurately assessed as a basis to sound experimentation. In this section we present

relevant carcass and growth-curve data for different breeds and crosses of lambs raised under conditions of feed and other environmental variables as nearly identical as is possible for numbers of stock in practical circumstances.

The lambs involved were of four different breeds and crosses, representing the main fat-lamb types of Canterbury—Corriedale, B.L. × Corriedale, S.D. × Corriedale, and S.D. × Romney. They were raised on the Department of Agriculture's experimental farm at Kirwee. All ewes were run on the same paddock from mating until weaning, while the lambs remained in this paddock until slaughter at approximately nine months of age. The pasture was of a good-quality rye-grass - white-clover type, showing a high proportion of red clover in late summer. The lambs may be considered as having been reared on a high plane of nutrition throughout, since no feed shortage occurred at any time. They were weighed at approximately monthly intervals.

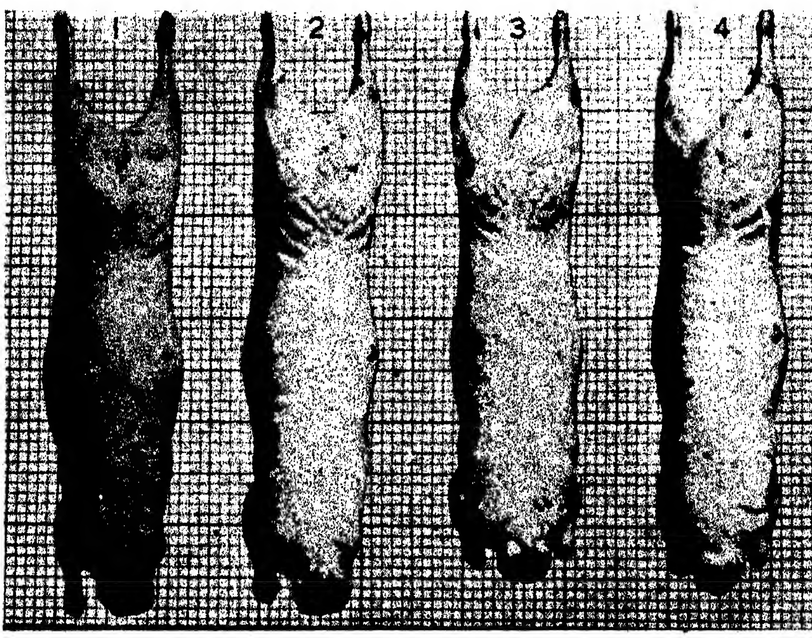


FIG. 1.—Best carcasses (all to same scale).

1, Corriedale; 2, B.L. × Corriedale; 3, S.D. × Corriedale; 4, S.D. × Romney.

As they were primarily involved in a project designed to test breed differences in susceptibility to parasitic infections under normal field-grazing conditions, they were not slaughtered at the normal age and weight for fat lambs, but were carried through until the early autumn. This situation does not detract in any way from the value of the carcass data resulting; rather has it enabled the examination of material just prior to the "hogget stage" as well as a study of growth over a much longer period than normally available in respect to Canterbury fat lamb.

The animals were slaughtered at the Kaiapoi works of the North Canterbury Farmers' Freezing Co. and carcass measurements (as described in Part I) taken. The right fore cannon of each lamb was also collected for subsequent measurement. Photographs were obtained of the "best,"

"worst," and "average" carcass in each group. For this purpose the carcasses were suspended from a gamble carrying a foot rule so that all photographs could be reproduced to scale.

I. COMPARISON OF "BEST" CARCASSES

Figure 1 shows the best carcass from each group all photographed to the same scale. Striking breed differences in conformation are apparent. The S.D. × Corriedale (No. 3) is of the most desirable type—a short "blocky" carcass, wide in the loin and gigots, with a short F measure and well-filled crutch. The shoulder is also well developed and the neck and fore legs short. The S.D. × Romney (No. 4) also shows a good type of carcass, slightly better in the loin than No. 3. However, the leg development is not as good as in the S.D. × Corriedale. The F measurement is longer, and since T is actually slightly shorter, this can be attributed to the poorer development of muscle and fat in the crutch. These two carcasses are of the same weight (53 lb.), but No. 4 is slightly longer and shows a rather larger neck—an undesirable feature, since it commands a relatively low price. The B.L. × Corriedale carcass (No. 2) shows a good loin development but a poorer "leg" than Nos. 3 and 4. Also, the shoulder is not as well developed and the neck and thorax—relatively cheap parts—are longer. The length of carcass (L) is greater than in any of the other three, although of comparable weight. The Corriedale carcass (No. 1) shows up poorly. The legs tend towards an undesirable Y shape. A long T measure is associated with a long F and poor filling in the crutch. The loin is not as well developed and, although the carcass is of the same length (L) as No. 3, the gigots are significantly narrower. The shoulder is poorly developed and the neck too long. This carcass is approximately 6 lb. lighter than the others.

Measurements of the carcasses shown in Fig. 1 are given in Table XVIII.

TABLE XVIII.—CARCASS MEASUREMENTS, "BEST" CARCASSES

Breed.	Wt.	G.	Th.	F.	T.	L.	Cannon.		Weight : M.	F − T.	T × G.
							Weight.	M.			
	lb.	Mm.	Mm.	Mm.	Mm.	Mm.	g.	Mm.		Mm.	Mm.
Corriedale ..	46	240	275	275	210	615	39·7	126	31·5	65	50,400
B.L. × Corriedale	52	252	289	252	202	632	46·1	126	36·6	50	50,904
S.D. × Corriedale	53	253	280	220	190	615	39·0	112	34·8	30	48,070
S.D. × Romney	53	252	283	231	188	618	32·5	107	30·4	43	47,376

Figure 2 shows the same carcasses all scaled to the same leg length (F). This illustrates the relative compactness of the carcass and is a photographic measure of the width of gigots and body length relative to the leg length. The superior conformation of the S.D. Cross lambs is outstanding. In contrast, the long-legged breeds—the Corriedale and the B.L. × Corriedale—show up poorly. These latter show a very poor gigot development relative to the length of leg, and the importance of short, thickly-fleshed legs is well illustrated by comparing the Corriedale (No. 1) with the S.D. × Corriedale (No. 3).

By applying the T × G formula (Part I) it is seen that the B.L. × Corriedale carries the greatest weight of bone and muscle, followed by the Corriedale, the S.D. × Corriedale, and the S.D. × Romney in that order. The estimated composition is shown in Table XIX and also the percentage of each tissue to the base Corriedale = 100.

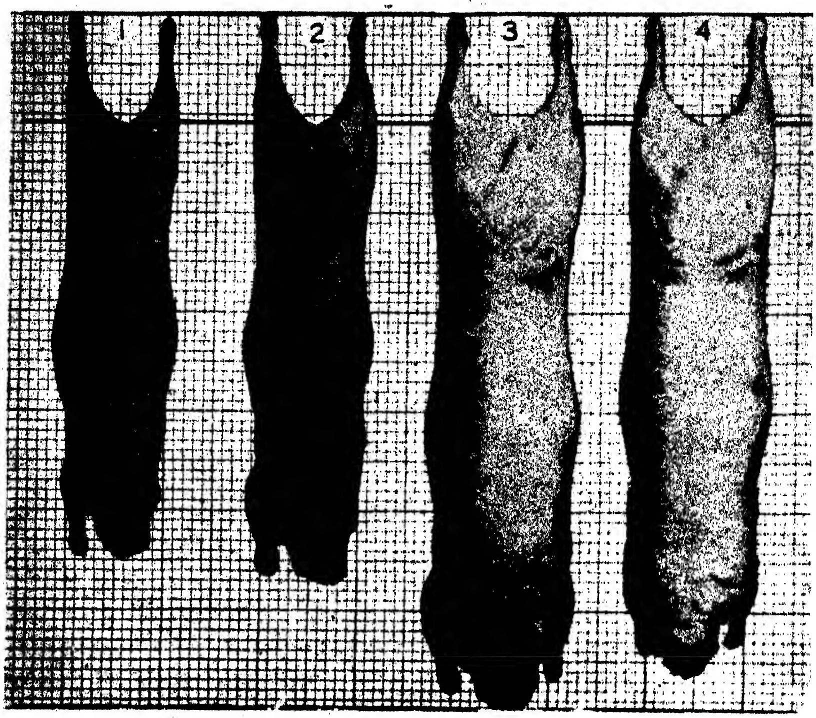


FIG. 2.—Best carcasses (all to same leg length).
1, Corriedale; 2, B.L. × Corriedale; 3, S.D. × Corriedale; 4, S.D. × Romney.

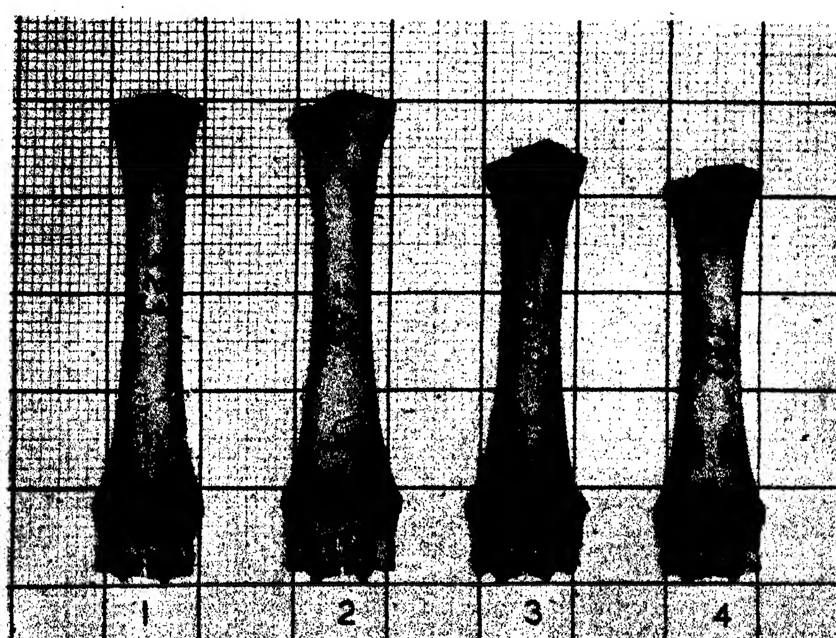


FIG. 3.—Cannon bones (best carcasses.)
1, Corriedale; 2, B.L. × Corriedale; 3, S.D. × Corriedale; 4, S.D. × Romney.

TABLE XIX.—COMPOSITION OF "BEST" CARCASSES

Breed.	Bone.		Muscle.		Fat.	
	Weight.	Percentage Corriedale.	Weight.	Percentage Corriedale.	Weight.	Percentage Corriedale.
	g.		g.		g.	
Corriedale	2,650	100	11,762	100	5,950	100
B.L. × Corriedale ..	2,681	101·2	11,907	101·2	8,429	141·6
S.D. × Corriedale ..	2,503	94·5	11,096	94·3	9,861	165·7
S.D. × Romney ..	2,460	92·8	10,897	92·6	10,103	169·8

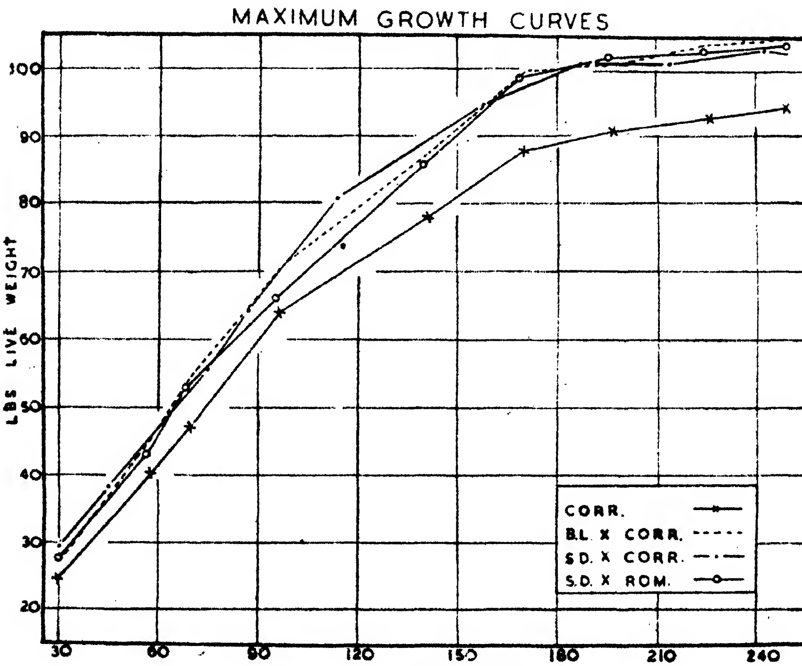


FIG. 4.

The length of cannon bone (Fig. 3) reflects the same order, as does also its weight. The Corriedale cannon (No. 1) is typically that of a relatively unimproved meat breed in its length and comparative narrowness. The B.L. (No. 2) shows a slightly longer bone which is broader in proportion and indicative of the semi-improved type of carcass. In contrast, the bones from the S.D. Cross lambs (Nos. 3 and 4) are relatively short and broad and typical of the improved meat animal.

These comparisons, along with the others of like nature presented in this study, strongly support Palsson's suggestion that the quality of a fat-lamb carcass is closely associated with the type of cannon bone. The practical applications, in view of the readily-observable nature of this part of the body, are obvious.

The importance of the rate of growth in its effect on carcass composition has been shown by McMeekan(4, 14). The growth curves followed by the lambs of Fig. 1 are shown in Fig. 4.

The lower rate of growth of the Corriedale throughout is noticeable. The other curves are fairly uniform, although from 90 to 150 days the S.D. × Romney has gained weight more slowly than the S.D. × Corriedale and the B.L. × Corriedale. It will be noticed that these two latter reached 70 lb. live-weight (at which lambs are ready for slaughter) at approximately the same time—*i.e.*, about fourteen weeks—the S.D. × Romney was about a week later, and the Corriedale took approximately another ten days.

II. COMPARISON OF "WORST" CARCASSES

Figure 5 shows the worst carcass from each group. All are very poorly "finished," although the Corriedale carcass (No. 5) was the only one graded "Second." The very poor type of carcass which a badly-grown Corriedale yields is well illustrated. The gigots are narrow and the legs long and Y

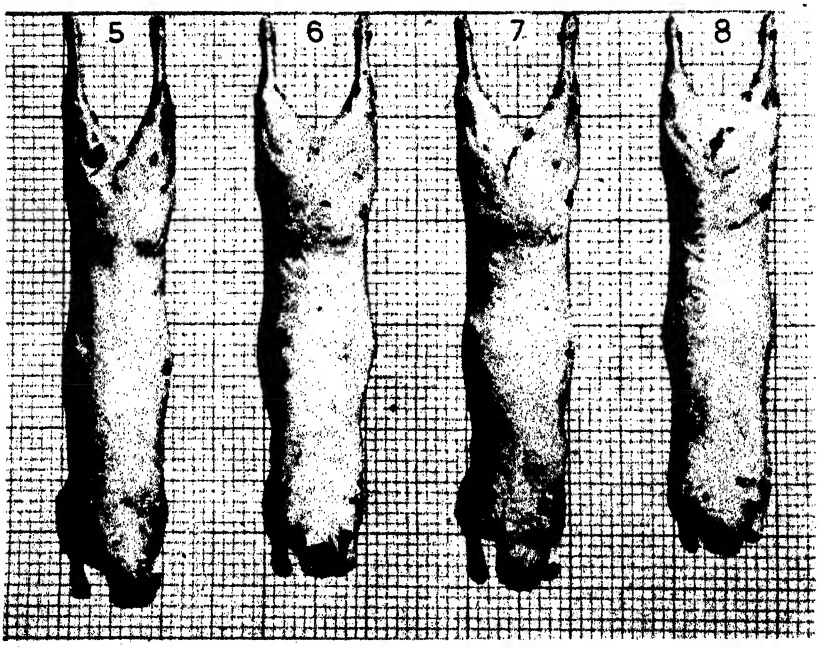


FIG. 5.—Worst carcasses (all to same scale).
5, Corriedale; 6, B.L. × Corriedale; 7, S.D. × Corriedale; 8, S.D. × Romney.

shaped, carrying shallow muscles and scarcely any fat. Poor loin development is evident. The shoulder is flat and the fore legs and neck long, although the fore end of the carcass shows rather better development than the hind end.

The S.D. × Corriedale (No. 7) shows the type of carcass which results when the cross throws to the Corriedale. The legs are long and poorly filled as compared with those of the "best" carcass in the group (Fig. 1, No. 3), which favours the S.D. The fore end shows typical Corriedale characteristics in the peaked shoulder resulting from prominent thoracic vertebræ and in the long fore legs and neck. In comparison, the hind end is not so poorly developed. Both these lambs were wethers, so that sex is not a determining influence. Although the S.D. × Romney carcass (No. 8) shows the best gigot development relative to the length of leg in this group, the loin is poorly developed as compared with that of the "best" carcass

(Fig. 1, No. 4) and the shoulder development weak. Poor "finish" is evident from the wrinkling over the shoulders. In contrast with the other carcasses of this group, the B.L. × Corriedale (No. 6) shows up comparatively well. Less variation was apparent in this breed group, all lambs being by the same sire. However, this carcass is markedly inferior to the "best" of the group (Fig. 1, No. 2). The leg length (F) is greater and the crutch poorly filled, while the shoulder is weak. Poorer muscle and fat development is evident throughout.

Carcass measurements for this group are shown in Table XX. It will be noted that, despite their age, weights of these "worst" carcasses are no better than normally expected from fat lambs of four to five months of age.

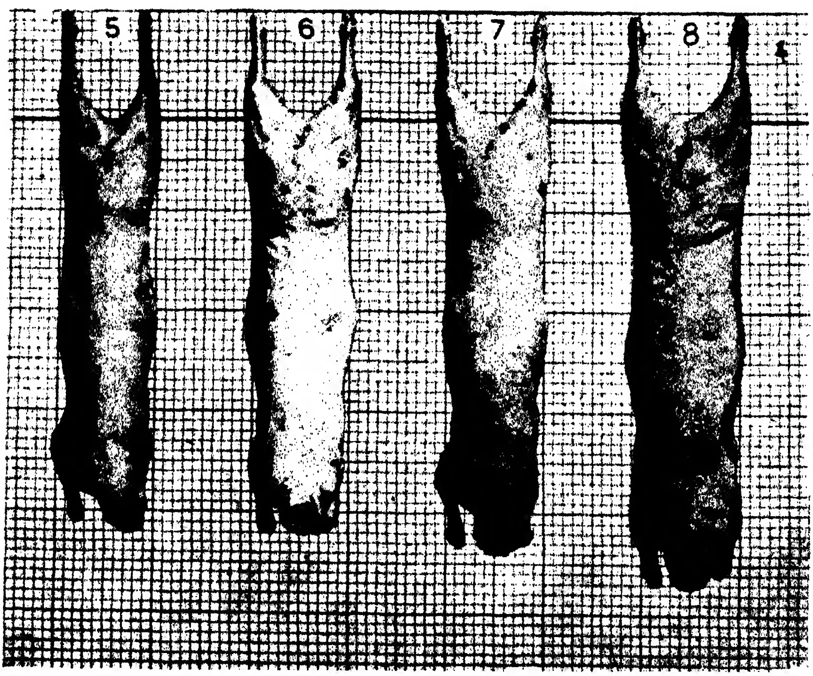


FIG. 6.—Worst carcasses (to same leg length).

5, Corriedale 6, B.L. × Corriedale 7, S.D. × Corriedale 8. S.D. × Romney.

TABLE XX.—CARCASS MEASUREMENTS, "WORST" CARCASSES

Breed.	Weight.	G.	Th.	F.	T.	L.	Cannon. Weight.	Cannon. M.	Weight: M.	F − T.	T × G
	lb.	Mm.	Mm.	Mm.	Mm.	Mm.	g.	Mm.		Mm.	Mm.
Corriedale ..	34	223	269	300	220	605	42·3	131	32·3	80	49,060
B.L. × Corriedale	37	235	264	275	200	610	37·9	118	32·1	75	47,000
S.D. × Corriedale	36	232	273	275	203	602	39·8	124	32·1	72	47,096
S.D. × Romney	33	228	239	237	175	558	28·3	103	27·5	62	39,900

Comparison of these carcasses scaled to the same leg length (F) (Fig. 6) emphasizes the better "leg" development of the S.D. × Romney (No. 8), although this is the lightest carcass in the group.

The poor development of the Corriedale (No. 5) in contrast with the other carcasses is thrown into relief. A long F measure combined with narrow gigots has resulted in a very bad hind quarter. The B.L. × Corriedale and the S.D. × Corriedale have the same F measure, but the B.L. × Corriedale is slightly wider in the gigots and hence shows a somewhat better leg development.

In spite of the poor quality of the Corriedale carcass, it may be seen (by reference to the T × G measure) that it carries the greatest weight of muscle and bone. It is in respect to fat that the biggest difference occurs, the Corriedale being markedly inferior. Table XXI shows the estimated composition of each carcass in this group.

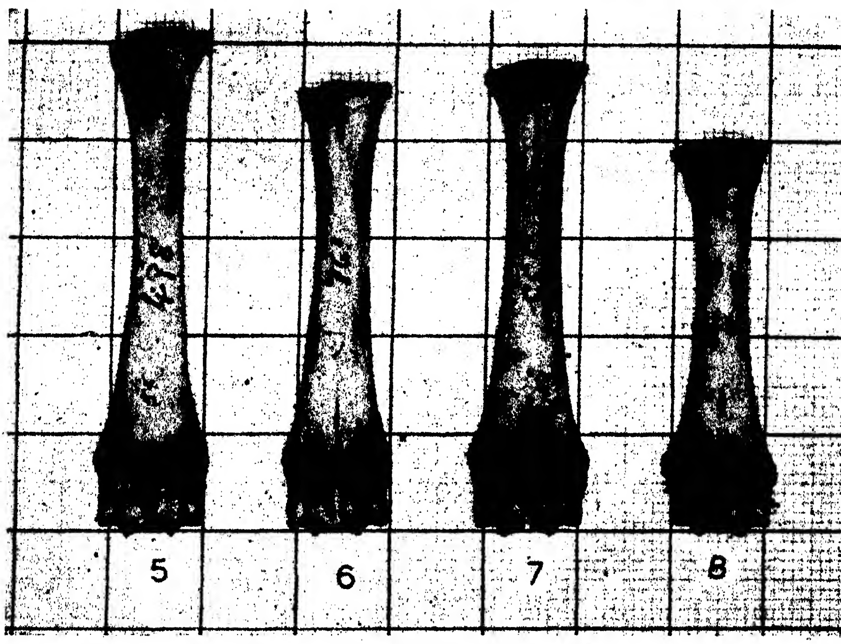


FIG. 7.—Cannon bones (worst carcasses).
5, Corriedale; 6, B.L. × Corriedale; 7, S.D. × Corriedale; 8, S.D. × Romney.

TABLE XXI.—COMPOSITION OF "WORST" CARCASSES

Breed.	Bone.		Muscle.		Fat.	
	Weight.	Percentage Corriedale.	Weight.	Percentage Corriedale.	Weight.	Percentage Corriedale.
	g.		g.		g.	
Corriedale	2,566	100	11,379	100	1,105	100
B.L. × Corriedale ..	2,436	94·9	10,790	94·8	3,152	285·2
S.D. × Corriedale ..	2,442	95·2	10,817	95·1	2,676	242·2
S.D. × Romney ..	1,989	77·5	8,759	77·0	3,859	349·2

The order for muscle and bone development is Corriedale, S.D. × Corriedale, B.L. × Corriedale, then S.D. × Romney. Here again both the lengths and the weights of the cannon bones reflect this order (Table XX and Fig. 7). It will be noted that the cannon of the "worst" S.D. × Corriedale (No. 7) resembles that of the Corriedale (No. 5), while the cannon of the "best" carcass (Fig. 3, No. 3) is more of the S.D. type.

The relative slimness of the shafts in this group of cannons as compared with those of the corresponding best carcasses (Fig. 3) serves to emphasize the desirability of *breadth* or *thickness* of bone as a characteristic in improved meat animals.

From the growth curves followed by the lambs in this group (Fig. 8) it can be seen that, while the rates of growth are consistently lower than those of the " best " lambs (Fig. 4), they have also been more subject to fluctuations. Inspection of the carcasses serves to emphasize the undesirability of this type of growth curve for the optimum development of the meat animal. From an economic point of view additional force is given to this argument by the fact that these lambs were very slow in reaching a suitable weight for slaughter. The earliest to reach the 70 lb. live-weight mark was again the S.D. × Corriedale (which took twenty-one weeks, as against fourteen weeks for the " best " lamb of its group). The B.L. Cross and the Corriedale were

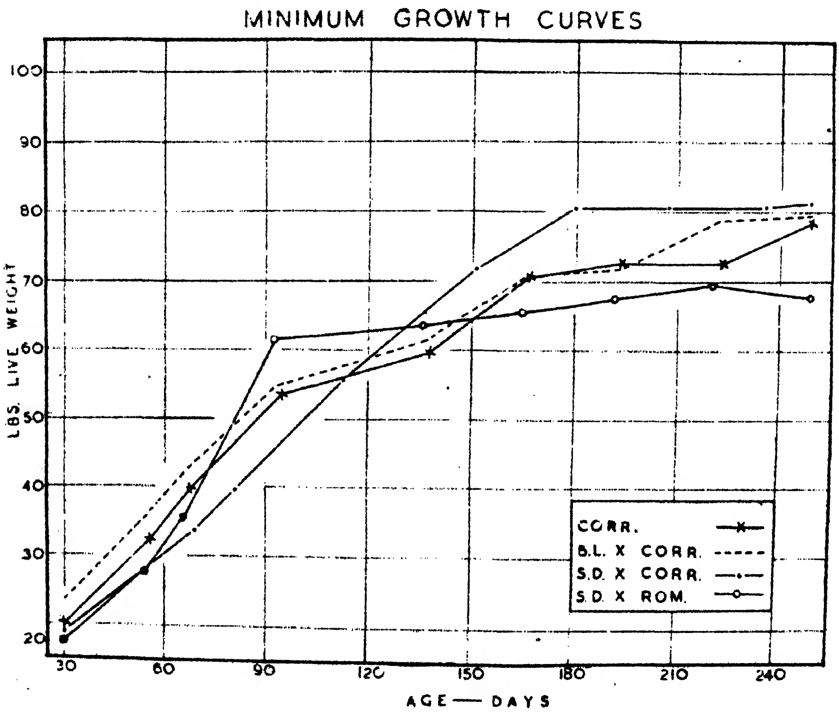


FIG. 8.

nearly six months old before they were fit to kill, while the S.D. × Romney took almost seven months to approximate the standard live-weight for slaughter. As has been mentioned, these lambs were nominally on a high plane of nutrition and the situation in this case has been due to other factors, but the same position arises when lambs are raised on a low plane of nutrition or, as more frequently occurs, when the feed-supply is subject to fluctuations(14). The undesirability of any impediment to the maintenance of a steady rate of gain from birth to slaughter is clear both from economic and qualitative aspects.

III. EFFECT OF RATE OF GROWTH

Figure 9 shows the average growth curves derived from the " maximum " and " minimum " curves (Figs. 4 and 8) and also the mean growth curve for all lambs, irrespective of breed.

Marked differences in the rate of growth are apparent. The divergences from the mean have been greatest during the period from 90 days to 150 days. From about three months after lambing the milk-supply of the ewe falls off very rapidly (Bonsma(9)). Some lambs suffer a setback at this time, while others, possibly because they have become more reliant on pasture, continue to grow rapidly. Weaning occurs when the lambs are about five months old, and the discrepancy between the growth curves of the fast- and slow-growing lambs is most marked at this time. Later there is a tendency for the growth ratio to even up. It will be noticed that during the last two months before slaughter the curves are approximately parallel—*i.e.*, the rate of gain has been the same in each group.

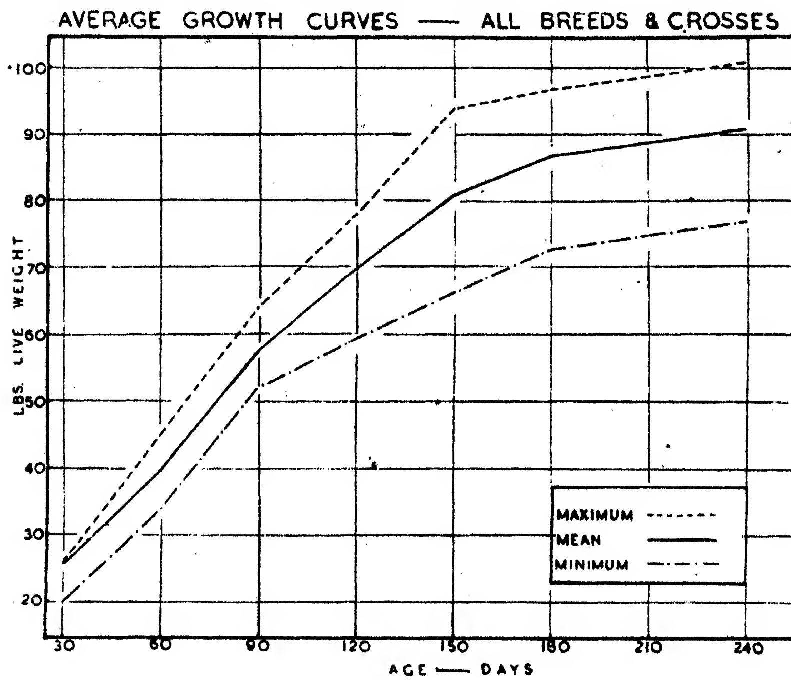


FIG. 9.

The difference between the groups in the age of attaining slaughter weight is very marked. While, on the average, this weight has been reached in 120 days, a fast-growing lamb may be fit to kill when about 112 days old, whereas one that has grown slowly may require nearly 170 days.

Table XXII shows the estimated carcass composition of lambs corresponding to these growth curves. The actual weight of each tissue has also been expressed as a percentage of the weight of that of the "mean worst" group.

TABLE XXII.—CARCASS COMPOSITION

—	Bone.		Muscle.		Fat.	
	Weight.	Percentage Mean Worst.	Weight.	Percentage Mean Worst.	Weight.	Percentage Mean Worst.
	g.		g.		g.	
Mean worst (slow growing)	2,356	100	10,045	100	2,700	100
Mean—all lambs ..	2,506	106	11,106	111	5,909	223
Mean best (fast growing)	2,577	109	11,430	114	8,568	317

It will be noticed that the order of magnitude of the percentage increases corresponds with the order of development of the tissues, bone, muscle, and fat, and provides an interesting demonstration of the principle established by McMeekan(4) for pigs and Verges(7) for sheep as to the differential effect of rate of growth on the animal body.

The lower section of Fig. 10 shows the smoothed mean-growth curve for all lambs. It has been shown (Brody(15)) that during the self-accelerating phase of growth the growth curve is made up of several segments or cycles.

When data plotted on arith-log paper are distributed about a straight line it may be concluded that the percentage rate of growth is constant.

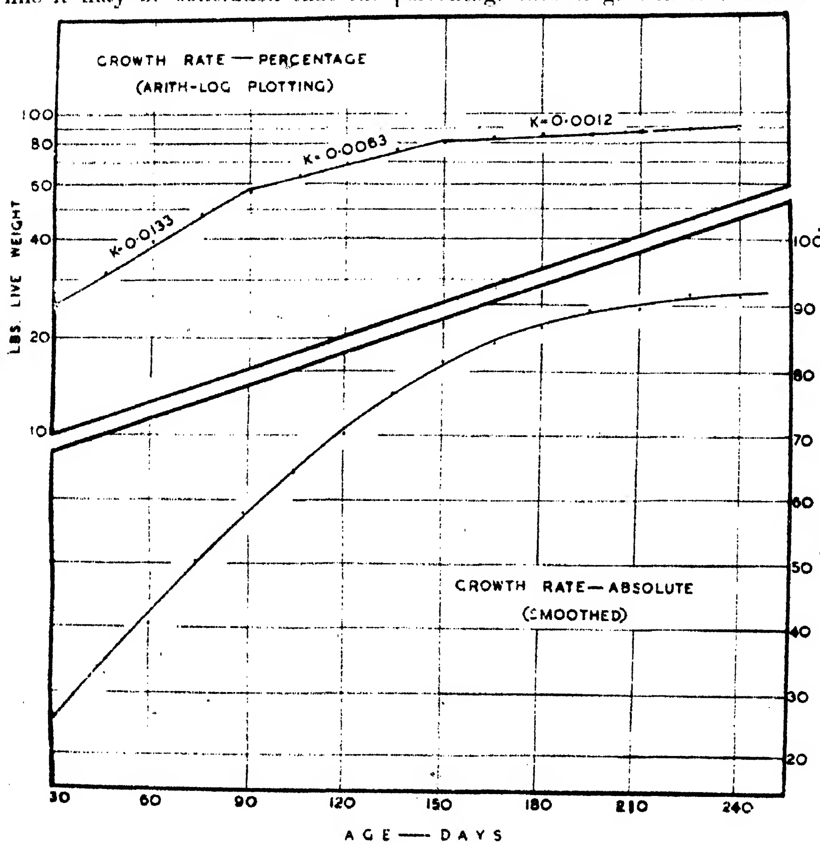


FIG. 10.

In the upper section of Fig. 10 the mean growth curve has been plotted in this way, and it is seen that the curve may be divided, if somewhat arbitrarily, into three distinct phases during which percentage rate is constant. The slope of the various segments has been calculated from the formula $W = Ae^{kt}$ in which W is the weight of the animal at the age t, e is the base of natural logarithms, and k is the relative (or, when multiplied by 100, the percentage) rate of growth(15). Thus, during the age period of 30 to 90 days, growth takes place at 1·3 per cent. per day. From 90 to 150 days, when pasture growth falls off and the milk-supply of the ewe decreases rapidly, a lower rate of growth is shown (0·63 per cent. per day). Weaning occurs when the lambs are approximately 150 days old, and is followed by another fall in growth rate to a constant

level of 0·12 per cent. per day. This rate persists until the lambs are approximately eight months old. On a gain per week basis these figures agree fairly closely with those obtained by Hammond(2). It appears that a "self-inhibiting" phase of growth has been reached, although it is unlikely that these lambs have reached the age of puberty, at which time Brody(15) states this phase is entered.

IV. BREED COMPARISONS

A. CONFORMATION, GROWTH, AND COMPOSITION

On the average the best type of carcass was found in the S.D. × Romney group, which also had the highest growth curve (Fig. 11). While some of the S.D. × Corriedales had better carcasses (see Fig. 1), greater variability was evident in this group, some of the carcasses resembling the Corriedale type (see Fig. 5). The effect of the sire on conformation can be seen by comparing the first three carcasses of each series (Figs. 1 and 5). The use

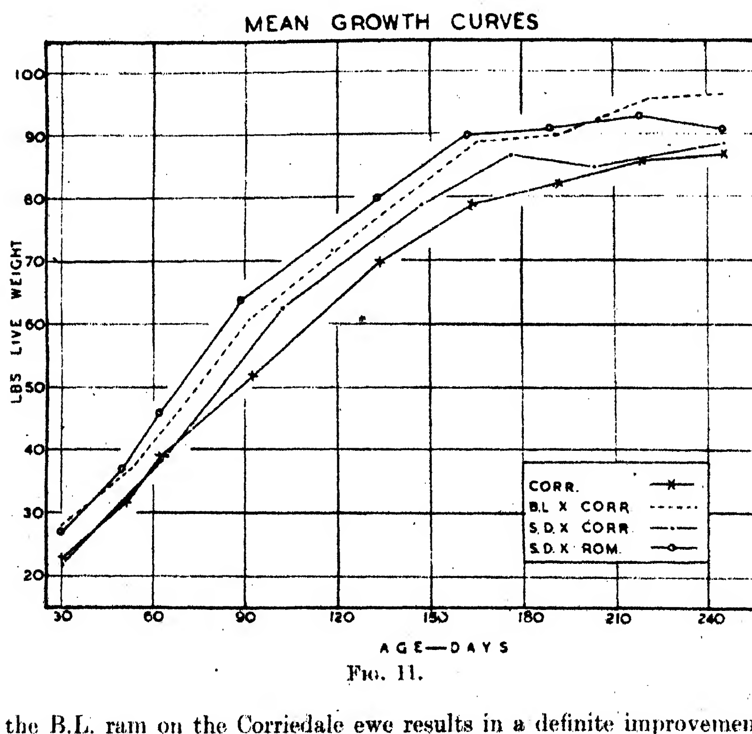


FIG. 11.

of the B.L. ram on the Corriedale ewe results in a definite improvement in the conformation of the lamb, but the S.D. ram normally reduces the proportionate length of leg and throws a much superior type of carcass.

The material provides a basis for breed comparisons. The B.L. × Corriedale group attained the highest mean carcass weight (46·4 lb.), followed by the S.D. × Romney (44·7 lb.), the S.D. × Corriedale (44·4 lb.), and the Corriedale (41·2 lb.). However, the S.D. × Romney group were the first to attain an average 70 lb. live-weight (time, 106 days). The mean-growth curve (Fig. 11) shows that this group, although slightly lighter than the B.L. × Corriedale at thirty days of age, gained weight more rapidly than any other group until surpassed by the B.L. × Corriedales approximately six weeks before slaughter. The rapidity of the early gains might be attributed to the superior milking ability of the Romney ewes combined with the early-maturing propensity inherited from the S.D. sires.

The B.L. × Corriedales, as a later-maturing cross, made a somewhat slower rate of growth, but continued to gain weight fairly steadily. As a group they reached the highest final live-weight (97 lb.), but took twelve days longer than the S.D. × Romney group to attain slaughter weight. The later-maturing Corriedales made the slowest gains and finished up with the lowest average live-weight (87 lb.). They did not reach the 70 lb. mark until 133 days old. The S.D. Corriedales followed the Corriedales very closely until they were about nine weeks old, when they began to increase in weight more rapidly, so that they were fit to slaughter ten days earlier than the Corriedales.

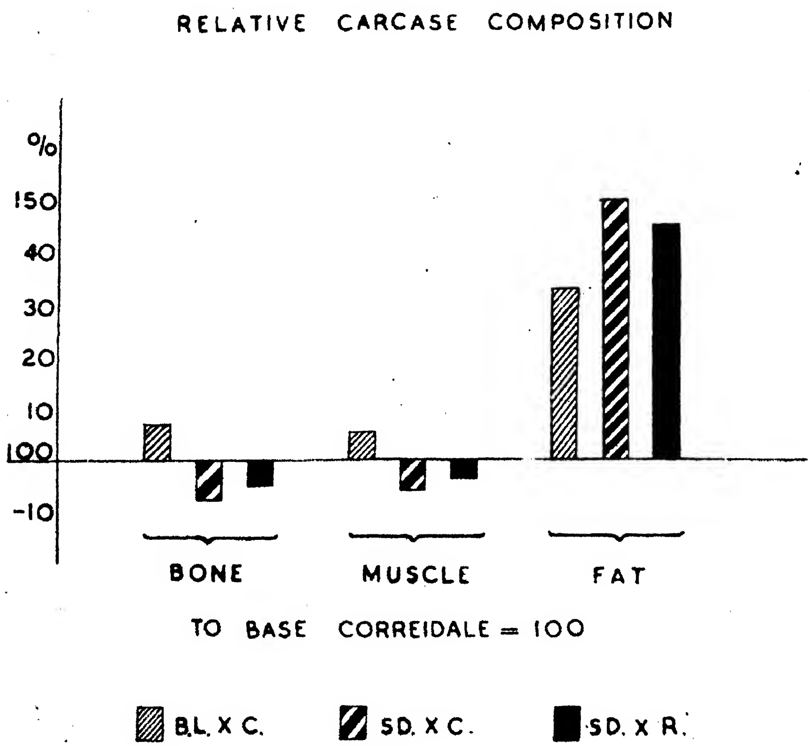


FIG. 12.

The relative mean carcass composition of the various breed groups as compared with the Corriedale is shown in Table XXIII and Fig. 12.

TABLE XXIII.—RELATIVE MEAN CARCASS COMPOSITION OF BREED GROUPS TO BASE CORRIEDALE = 100

Group.	Bone: Percentage Corriedale.	Muscle: Percentage Corriedale.	Fat: Percentage Corriedale.
Corriedale	100	100	100
B.L. × Corriedale	105	105	134
S.D. × Corriedale	93	93	152
S.D. × Romney	96	96	147

The B.L. × Corriedales show higher percentages of both muscle and bone than the Corriedales, but the other two groups are lower, the S.D. × Corriedales being slightly lower than the S.D. × Romneys. The most marked differences, however, are shown in respect to fat development. All groups have a much higher percentage of this tissue than the Corriedales. On an average the S.D. × Corriedales carry the most fat, followed fairly closely

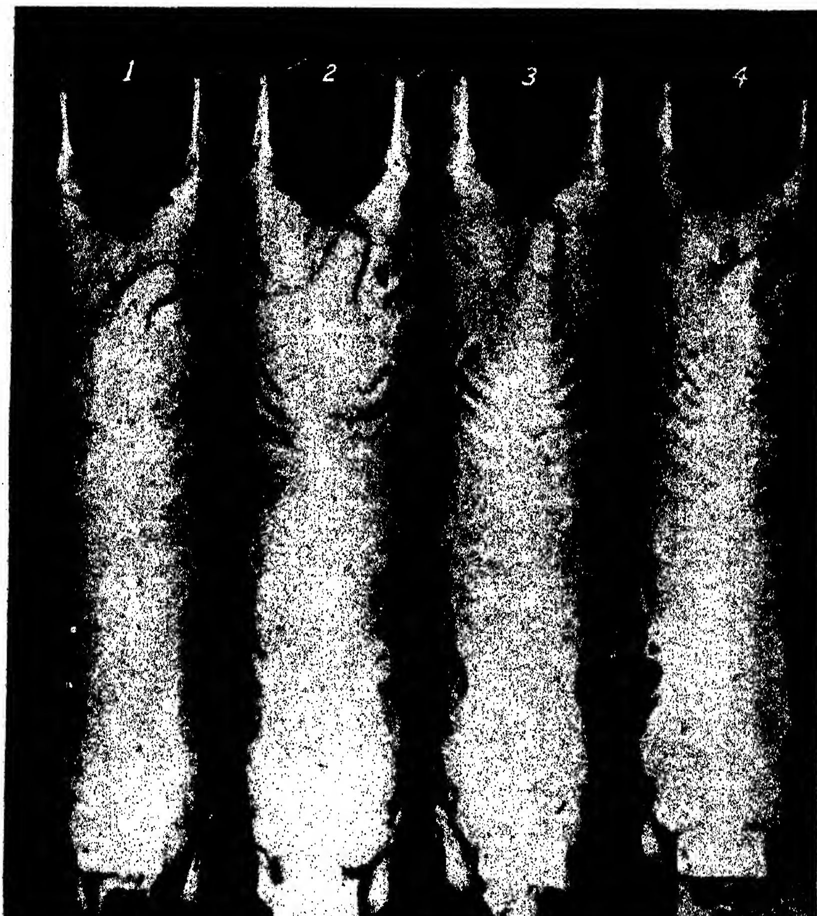


FIG. 13.—Average grade 4 carcass from each group

1, Corriedale; 2, B.L. × Corriedale; 3, S.D. × Corriedale; 4, S.D. × Romney

by the S.D. × Romneys. The later-maturing B.L. × Corriedales fall some way behind, but are still greatly in advance of the Corriedales.

The slight difference in order of bone, muscle, and fat development in these "mean" data as compared with the "best" and "worst" data is understandable in view of the fact that the latter are based on single lambs, the growth rates of which deviated markedly from the means.

B. COMPARISON OF MEAN CARCASS MEASUREMENTS

(*a*) *Width of Gigots (G).*—The Corriedales have narrower gigots than any of the other three classes, between which no differences exist. Comparison with the data of Table VI illustrates the effect of maturity in increasing the size of the hind quarter as measured by G. It is of interest also to note that increased maturity has not merely reduced the relative differences between the breeds in relative development of G, but has reversed the order in some cases. (Compare Corriedale and S.D. × Corriedale, Tables VI and XXIV.)

(*b*) *Length of Tibia + Tarsus (T).*—There is no difference in this measurement between the Corriedales and the B.L. × Corriedales or between the two S.D. Cross groups, though both these latter groups are shorter in T than either of the other two groups. The Corriedales show a relatively greater increase in this measurement with age than do the S.D. Cross lambs, as may be seen by comparing Table XXIV with Table VII, a result in line with the later-developing characteristics of an "unimproved" meat breed.

(*c*) *Product of Length of Tibia + Tarsus and Width of Gigots (T × G).*—The order of the various groups for muscle and bone development as measured by T × G has been discussed already. The significance of the inter-breed differences is shown in Table XXIV.

(*d*) *Length of Leg (F).*—Differences in leg length are closely related to differences in T. The Corriedales do not differ from the B.L. × Corriedales, nor is there any significant difference between the two S.D. Cross groups. As might be expected, the S.D. Cross groups are shorter in F than either of the other groups.

(*e*) *Depth of Thorax (Th).*—No breed differences in this measurement appear (Table XXVII). This result may be contrasted with those of Table XI, where the heavy Corriedale lambs are deeper in the thorax than the heavy S.D. Cross lambs. With increase in age S.D. Cross lambs therefore show a relatively greater increase in Th than do Corriedales, a result in line with the late-developing nature of body depth(2, 4).

(*f*) *Length of Body (L).*—The S.D. × Corriedale lambs are shorter in the body than any of the other groups. The B.L. × Corriedales have the greatest mean length, but the difference between them and the Corriedales is not significant. S.D. × Romneys occupy an intermediate position.

TABLE XXIV.—BREED COMPARISONS OF CARCASS MEASUREMENTS

(Mean measurements (millimetres) and significance of differences)

——	Corriedale.	B.L. × Corriedale.	S.D. × Corriedale.	S.D. × Romney.
	Width of Gigots (G)			
Corriedale	233·76	SS	SS	SS
B.L. × Corriedale	..	247·14	NS	NS
S.D. × Corriedale	..	..	244·19	NS
S.D. × Romney	..	..	..	246·41
	S.E. group means = 2·17			
	Length Tibia + Tarsus (T)			
Corriedale	208·41	NS	SS	SS
B.L. × Corriedale	..	205·79	SS	SS
S.D. × Corriedale	..	..	188·60	NS
S.D. × Romney	..	..	..	191·12
	S.E. group means = 1·93			

SS = significant at 1 per cent. level; S = significant at 5 per cent. level; NS = not significant.

TABLE XXIV.—BREED COMPARISONS OF CARCASS MEASUREMENTS—*continued*

—	Corriedale.	B.L. × Corriedale.	S.D. × Corriedale.	S.D. × Romney.
Product of Length of Tibia + Tarsus and Width of Gigots (T × G)				
Corriedale	48,713·4	S	S	NS
B.L. × Corriedale	..	50,877·4	SS	SS
S.D. × Corriedale	..	..	46,062·8	NS
S.D. × Romney	..	..	..	47,130·2
S.E. group means = 716·43				
Length of Leg (F)				
Corriedale	276·12	NS	SS	SS
B.L. × Corriedale	..	268·00	SS	SS
S.D. × Corriedale	..	..	241·40	NS
S.D. × Romney	..	..	..	241·21
S.E. group means = 3·27				
Length of Body (L)				
Corriedale	616·6	NS	SS	NS
B.L. × Corriedale	..	625·9	SS	SS
S.D. × Corriedale	..	..	593·8	S
S.D. × Romney	..	..	..	607·8
S.E. group means = 4·82				

SS = significant at 1 per cent. level; S = significant at 5 per cent. level; NS = not significant.

(*g*) *Length of Right Fore Cannon (M).*—As for T and F, there are no differences in cannon length between the Corriedales and B.L. × Corriedales or between the S.D. Cross groups, and the latter groups are shorter than the former. The Corriedales have shown a slightly greater increase in length with age than have the S.D. Cross lambs.

(*h*) *Weight of Right Fore Cannon.*—The B.L. × Corriedale lambs show the heaviest cannon bones. Corriedales are also heavier than S.D. × Corriedales.

TABLE XXV.—BREED COMPARISONS IN CANNON BONE LENGTH AND WEIGHT
(Mean measurements and significance of differences)

—	Corriedale.	B.L. × Corriedale.	S.D. × Corriedale.	S.D. × Romney.
Length of Cannon (M)				
	Mm.	Mm.	Mm.	Mm.
Corriedale	123·47	NS	SS	SS
B.L. × Corriedale	..	123·79	SS	SS
S.D. × Corriedale	..	..	110·00	NS
S.D. × Romney	..	..	..	109·06
S.E. group means = 1·34				
Weight of Cannon				
	g.	g.	g.	g.
Corriedale	38·69	SS	S	NS
B.L. × Corriedale	..	43·44	SS	SS
S.D. × Corriedale	..	..	35·08	NS
S.D. × Romney	..	..	..	35·92
S.E. group means = 1·04				

SS = significant at 1 per cent. level; S = significant at 5 per cent. level; NS = not significant.

Since there is no significant difference in length between the Corriedales and the B.L. × Corriedales, the large difference in weight must be attributed to differences in thickness. This is clear from the weight : length ratios of Table XXVI.

TABLE XXVI.—WEIGHT : LENGTH RATIOS

Corriedale	31·34
B.L. × Corriedale	35·09
S.D. × Corriedale	31·89
S.D. × Romney	32·94

DISCUSSION

The data presented in Parts I, II, and III of this paper have placed us in a position to summarize in general terms the major carcass characteristics of the principal breeds and crosses of New Zealand fat lamb. In addition, they have provided considerable information on the absolute and relative effects of such factors as weight, nutrition, sex, and age. Some information is also available on the effects of rate of growth in modifying carcass conformation and composition. To facilitate such generalizations as seem permissible, the mean carcass measurements and compositions are summarized in Tables XXVII and XXVIII.

TABLE XXVII.—MEAN CARCASS MEASUREMENTS

Group.	Weight.	G.	Th.	F.	T.	L.	Cannon. Weight.	Cannon. Length.	F − T.	T × G.
Breed and weight (five months)	lb.	Mm.	Mm.	Mm.	Mm.	Mm.	g.	Mm.	Mm.	Mm.
S.D. Cross—										
Light	34·24	220	248	230	175	547	30·7	106	55·1	38,474
Heavy	38·48	223	253	231	179	559	32·7	108	51·9	39,894
Corriedale—										
Light	34·60	218	252	259	190	573	36·2	116	65·3	41,407
Heavy	38·79	226	261	264	195	587	39·1	120	68·8	44,169
Romney × Corriedale—										
Light	34·20	217	254	245	185	576	..	..	60·2	40,116
Heavy	39·00	223	264	256	191	592	..	..	64·4	42,679
Breed and feed (five months)—										
S.D. Cross—										
Milk	36·21	221	250	230	177	553	31·7	107	56·6	39,123
Rape	35·76	224	251	228	180	548	30·3	106	48·1	40,187
Corriedale—										
Milk	37·13	222	257	262	193	581	37·7	118	67·1	42,870
Rape	35·12	219	257	249	193	561	35·6	116	56·3	42,275
Sex (five months)—										
S.D. Cross—										
Wethers	36·48	223	254	230	179	553	32·5	108	50·9	39,926
Ewes	35·63	221	246	230	175	550	29·4	105	54·6	38,565
Kirwee (nine months)—										
Corriedale	41·24	234	274	276	208	617	38·7	123	67·7	48,713
B.L. × Corriedale ..	46·36	247	278	268	206	626	43·4	124	62·2	50,877
S.D. × Corriedale ..	44·41	244	269	241	189	594	35·1	110	52·9	46,063
S.D. × Romney ..	44·71	246	271	241	191	608	35·9	109	50·1	47,130

TABLE XXVIII.—ESTIMATED MEAN PERCENTAGE CARCASS COMPOSITION

Group.	Bone.	Muscle.	Fat.
Breed and weight (five months)—			
S.D. Cross—			
Light	12·64	52·42	32·62
Heavy	12·00	48·71	37·01
Corriedale—			
Light	14·16	55·07	28·53
Heavy	14·00	54·58	29·14
Romney × Corriedale—			
Light	13·62	55·20	28·92
Heavy	13·19	52·12	32·37
Breed and feed (five months)—			
S.D. Cross—			
Milk	12·32	50·61	34·82
Rape	13·03	52·90	31·79
Corriedale—			
Milk	13·91	55·05	28·72
Rape	14·39	57·26	26·08
Sex (five months)—			
S.D. Cross—			
Wethers	12·61	51·33	33·57
Ewes	12·18	50·37	34·95
Kirwee (nine months)—			
Corriedale	13·60	60·39	23·13
B.L. × Corriedale	12·76	56·67	27·52
S.D. × Corriedale	11·83	52·23	33·60
S.D. × Romney	12·05	53·48	32·15

Throughout the study the pre-eminence of the S.D. as the sire breed in fat-lamb crosses is strikingly demonstrated. S.D. Cross lambs have a superior conformation in terms of British market requirements, for which general blockiness of form, short legs, deep muscles, well-developed hind quarters, and high proportion of fat at light weights place it in a class well above the Corriedale, Romney × Corriedale, and B.L. × Corriedale. The major weakness of the S.D. Cross lamb—and this was apparent both in its cross with the Corriedale and Romney—is a lower yield of muscle and an excessively high yield of fat as compared with other breeds of the same weight class. As McMeekan and Clarke(3) have pointed out, this situation results in a higher calorific value (though a lower protein yield) per carcass and per pound. In normal times, when the consumer is free to exercise preference, this is a real disadvantage in view of the increasing demand for lean rather than fat meat. In times of war, with the consequent food-shortage problems, the high nutritive value of the S.D. Cross lamb has obvious advantages.

In marked contrast, the straight Corriedale is by far the poorest of the different breeds and crosses studied. Long and narrow, with shallow muscles, a poorly developed hind end, wasteful bone, and an insufficiency of fat, it falls well below the other types in quality. In addition, the Corriedale shows up less favourably when "finished" on rape or when retained to heavy weights under normal pasture conditions. Since this breed does not fatten readily "off the mother," these latter characteristics place it at an even greater disadvantage. Its greatest merit lies in its high muscle (protein) yield. It is unfortunate, in view of these qualities, that so much use has to be made of this breed. Such use is unavoidable in view of the fact that the whole economy of our fat-lamb industry depends on a cheap supply of breeding ewes. Corriedales are not kept deliberately for

fat-lamb, but for wool, production. They are necessary for this purpose on fine-wool country and for maintaining the ewe-supply for adjoining fat-lamb-producing areas. In the process they yield wether lambs that must be marketed as meat. Since improved quality follows improved rate of growth, there is a sound case for providing such lambs with optimum nutritive conditions. On the same argument, efforts to improve the milking-capacity of the Corriedale ewe—as yet an untouched research field in New Zealand—might be well worth while. Improved quality would follow not merely in the straight Corriedale lamb, but also in progeny by improved fat-lamb sires.

The B.L. × Corriedale lamb occupies an intermediate position. The sire here has effected some degree of improvement, the cross approaching the desired blockiness of form. The extremely long legs of the B.L., however, places it at some disadvantage. The B.L. shows up as a later-developing breed than the S.D., and it is unfortunate that the only data available on this cross are for lambs of heavy weights and greater ages than normal in fat-lamb production, thus conferring an advantage on the cross in these comparisons. From the general trend of results it seems reasonable to conclude that the improvement noted would not be so pronounced at lighter weights and younger ages. This summary of the B.L. as a fat-lamb sire is in line with its decreasing use in practice in favour of the S.D., and its retention mainly for specialized local trade requirements.

Carcasses from the crossing of two breeds recognized as fat-lamb-ewe breeds—Romney × Corriedale—yield results in line with the attributes of their parents. Lambs are far from ideal in conformation, but are a definite improvement on the Corriedale. This is in line with the commonly-accepted practical opinion as to the superior carcass conformation of the Romney, to which the improvement must be attributed. Lambs of this type are unlikely to be a permanent feature of the industry, coming mainly as by-products from flocks on suitable country using the Romney ram to grade up Corriedale ewes to the Romney type.

Only a limited amount of data is available for the S.D. × Romney, the most popular and most used fat-lamb cross in the North Island and in Southland. Though showing little difference from the S.D. × Corriedale, the results should be accepted with reservation both in view of the numbers involved and the excessive age of the individual animals.

Of the factors other than breed which have been shown in this study to affect carcass quality, increasing weight increases all measurements. The differences between the light-weight groups and heavy-weight groups, however, do not show clearly any marked relationship between such increases and the relative order of development of the different parts as might be expected from fundamental growth studies (4, 5, 15). This is probably due partly to the small difference in mean carcass weight of grade 2's and grade 8's, and partly to the probability that lambs qualifying for slaughter as grade 2's will be those which are relatively earlier maturing and which accordingly show good development of late-developing regions.

Study of the effect of the two major nutritive differences operating in commercial fat-lamb production has yielded extremely interesting results. The influence of milk versus rape fattening is obviously affected by breed. This is clear from the fact that lambs of superior fat-lamb type (Down Cross) improved on rape feeding, while lambs of the unimproved type (Corriedale) deteriorated in quality. Quite obviously a strong breed/feed interaction effect exists. Calculation of this interaction from the analyses of variance

data shows this to be highly significant and of the order of 3·0 per cent. to 5·1 per cent. for the most important measurements. It is suggested that the probable explanation of this situation is that most Down Cross lambs are capable of being fattened to the desired conformation and retain this capacity for a considerable time. Small lambs of this type, too light to go fat off the mothers, can be very efficiently finished on rape, to which they respond in a manner similar to animals changed from a low to a high plane of nutrition(4, 5). Conversely, the Corriedale yields fewer lambs fat off the mother, leaving behind for subsequent rape fattening animals that are so "late developing" in character that even improved nutrition results merely in additional growth rather than in fattening.

Sex differences have been shown to exist and to be significant. In conformation the ewe lamb has a small advantage over the wether, while in composition the reverse is the case. Though not of great commercial significance, sex effects are sufficiently important to warrant consideration in experimental planning, while the relative fat-development situation is of interest and importance in studies of fat metabolism. Sheep appear to resemble cattle in this respect, the natural female tending to lay down fat more readily than the castrate male. Since excessive fat in lambs is likely to prove an embarrassment in post-war marketing, the possibilities of non-castration of male lambs seems worthy of investigation. Sheep of the breeds under review are not sexually mature until they are eight to ten months of age, so that such a practice is not likely to result in any harmful effects upon flavour or texture of the resulting meat.

While no direct measure of the influence of age has been obtained, comparison of the appropriate breed groups of Parts I and II permits some assessment of its effect as between lambs marketed at approximately five months and lambs carried on to the age of nine months under normal pasture conditions. Table XXIX shows the various measurements at nine months as a percentage of those on milk lambs at *five* months.

TABLE XXIX.—MEAN MEASUREMENTS AT NINE MONTHS EXPRESSED AS A PERCENTAGE OF MEAN MEASUREMENTS AT FIVE MONTHS

Group.	Weight.	G.	Th.	F.	T.	L.	Cannon. Wt.	Cannon. M.	F – T.	T × G.	Bone.	Muscle.	Fat.
S.D. Cross	127	110	108	105	107	107	111	103	93	118	118	127	118
Corriedale	111	105	107	105	108	106	103	104	101	114	109	122	89

S.D. Cross lambs increased their weight 27 per cent. and the respective carcass measurements from 3 per cent. to 10 per cent. Corriedale lambs, for a smaller weight increase of 11 per cent., show almost the same percentage measurement increases as the Down Cross, thus lending weight to the suggestion advanced above as to the late-developing character of the Corriedale breed. As indicated by the relative increase in bone, muscle, and fat, most of the increase in weight with age of the Corriedale lambs consists of bone and muscle, the late-developing fat having actually decreased in the older and heavier lambs.

Relevant to the above discussion, and of considerable importance from many angles, is the relative effect of all these factors. The analyses of variance data has permitted an estimate of the percentage of the total variance in each carcass measurement associated with breed, weight, feed, and sex. These are summarized in Table XXX.

TABLE XXX.—APPROXIMATE PERCENTAGE OF VARIANCE THAT CAN BE ASSOCIATED WITH GROUPING

Measurement.	Breed.		Weight : Five Months.	Feed : Five Months.	Sex : Five Months.	Interaction.	
	Nine Months.	Five Months.				Breed and Weight.	Breed and Feed.
G	29	1	17·0	0·0	3	1·2	3·0
T	59	48	0·6	2·5	7	..	..
T × G	28	..	..	..	..	..	..
F	72	58	1·5	0·5	0	..	3·8
F T	..	19	0·0	4·2	5	1·5	3·5
Th	3	4	17·0	0·1	4	1·2	3·0
L	14	31	8·4	2·7	0	..	5·1
Cannon length ..	66	56	4·1	1·0	14	0·3	..
Cannon weight ..	36	31	7·3	3·8	22	19·1	..

The two columns shown for "breed" are not strictly comparable, since different breeds are involved in the two sets of data, in addition to the age difference. It is clear, however, that, of the factors studied, breed contributes most to variability, accounting for from 20 per cent. to 50 per cent. of the total variance. Weight is of much less importance, but this result must be related to the relatively small difference (approximately 4 lb.) in the weight groups involved. Feed effects account for still less of the total variance while sex appears to exert a comparable influence. The significant breed feed interaction effects have already been commented on. The magnitude of the breed effects upon what are essentially measurements of conformation is of special interest in view of the recently reported work of McMahon(16) and others(17) as to the low intensity of inheritance (paternal half-sib. and dam-progeny correlations) of conformation in the sheep. The apparent conflict between our results and these findings can be resolved in terms of a "dominance" explanation. The low heritability correlations referred to for conformation have been obtained from studies, within a breed, where additive gene effects are apparently most important. In this work, extremes in breed types have been crossed with marked effects upon the conformation of progeny, suggesting that the short-boned structure of an "improved" meat breed has exerted some degree of dominance over the longer skeletal form of the "unimproved" breed. It seems reasonable to suggest that, while differences in conformation within a breed may not be inherited to a degree which permits any effective control through straight selection, considerable control over the conformation of sheep can be obtained by interbreed crosses of appropriate types. This is made practical use of by all specialized producers of fat lambs.

Several interesting points may be noted in connection with the study of the Kirwee lambs. In the first place, a surprising degree of variability is shown in the resulting growth rates, carcasses, and measurements within each breed group as well as between the various groups. Even within the B.L. × Corriedale group, where all lambs were by the same sire, there was still an appreciable amount shown. This variability may have been due to different levels of efficiency in utilizing food leading to differences in the rate of growth, to different inherent growth rates, or to the different grazing abilities of the individual lambs, so that, while they were all nominally on the same plane of nutrition, very different planes were in reality self-imposed upon them. The influence of accidental factors such as parasites, variable shelter effects, and good fortune in selective grazing must not be overlooked. Whatever the fundamental cause, the variation exhibited seems to cast

doubt on the validity of claims that sheep reared as groups in the same field over the same period are under precisely the same nutritive conditions. Inherent causes may influence the results to an extent that provides strong argument for the use of inbred lines under individual feeding conditions in experiments designed to measure small differences. Standard methods of statistical analysis of data in inheritance studies and progeny test work are based on the assumption that small group feeding conditions are identical.

Though a case can be made for uniform material and individual feeding in experiments involving small differences, it is of special interest to note that the number of lambs involved in these experiments (average, sixteen) is adequate to permit differences in the more important carcass measurements to show up to a statistically-significant degree under field conditions where the factor or treatment (in this case, breed) under study is likely to be responsible for at least 20 per cent. of the total variance.

In conclusion, reference must be made to one or two further points of importance arising from this study. Throughout the carcass comparisons, considerable support has been afforded the contention of many writers that short, thick bone is a characteristic of the improved meat animal. The strong correlation between bone and muscle has been stressed. These views are contrary to those held by most purebred breeders and even commercial breeders, who tend to favour light, thin bone in their selection work. Likewise, the fundamental importance of rate of growth to carcass development is well illustrated in various parts of the study. A growth curve characteristic of lambs under pasture conditions has been constructed, and analysed in such a way as to emphasize the profound influence of feed-supply upon rate of growth. It is hoped that, in view of the dearth of information upon rate of growth of New Zealand sheep, these curves may be of value to other workers in this and allied fields for comparative purposes, as descriptive of the behaviour of normal grass-fed lambs from one of the major fat-lamb-producing areas.

At the outset of this study reference was made to the conception of D'Arcy Thompson as to the orderly progress of biological studies from simple observations to mathematical descriptions. If this work has any virtue, it lies in its presentation of factual information on one of our major industries where, hitherto, practical observational experience has dominated outlook and progress.

ACKNOWLEDGMENTS

Finance for the work herein reported was provided by a research grant from the Department of Scientific and Industrial Research, to which our thanks are due. We would also like to acknowledge the assistance of P. G. Stevens and R. Lambert for their assistance in collecting part of the measurement data, of P. R. McMahon for statistical advice, and of R. Blackmore for photographic assistance. Our appreciation is further due to T. K. Ewer, Animal Research Division, Department of Agriculture, for his generous permission to take over for post-slaughter examination the sheep involved in Part III, and for providing the live-weight data of these animals. We also wish to thank the North Canterbury Farmers' Freezing Co., without whose co-operation the work would not have been possible.

REFERENCES

(14) McMEEKAN, C. P.; STEVENS, P. G.; and LAMBERT, R. C. (1942): *N.Z. J. Sci. & Tech.*, 4A, 215A.
(15) BRODY, S. (1928): "Growth," Robbins, W. J., *et al.* *Yale Univ. Press.*
(16) McMAHON, P. R. (1944): *Proc. N.Z. Soc. An. Prod.*, 70.
(17) ENSMINGER, M. E., *et al.* (1943): *J. An. Sci.*, 2, 157.

THE SYMPTOMS OF ERGOT POISONING IN SHEEP

By I. J. Cunningham, J. B. Swan, and C. S. M. Hopkirk, Animal Research Station, Department of Agriculture, Wallaceville

[*Received for publication, 7th July, 1944*]

Summary

The chief lesions in sheep poisoned by *Claviceps purpurea* are inflammation and ulceration of the mucosa of the alimentary tract.

In seasons when suitable conditions prevail the pasture grasses of some sheep-grazing areas may become infected with *Claviceps purpurea*. The presence of the ergot sclerotia as conspicuous black bodies on the ripening seed-head has led to conjecture regarding their influence in promoting disease in the sheep. It is, for example, popularly believed that " rye-grass staggers " is a form of ergot poisoning, and from time to time various other diseases of sheep have been ascribed to the ingestion of ergot sclerotia with the fodder.

No account of ergot poisoning in sheep has appeared in the literature except a preliminary account by one of us(1), which dealt with the results obtained on only four experimental animals. This provided insufficient data on which to base an opinion as to the role of ergot in the cause of disease in the sheep ; further work was therefore undertaken, and the results are presented in this paper.

Perennial rye-grass (*Lolium perenne* L.) is the chief component of sheep pastures which become infected with ergot. Therefore the ergot employed for experimental feeding was the strain which grows on perennial rye-grass. Pure specimens of ergot were not available, and it was necessary to employ rye-grass-seed cleanings, separated in the commercial cleaning of seed. Four different samples were obtained, the proportion of ergot sclerotia, by weight, in the different samples being 21, 7, 5, and 2·3 per cent. respectively.

For dosing, the ergot-seed mixture was finely ground, suspended in water, and administered through a stomach-tube. Eighteen sheep were treated ; individual doses of ergot sclerotia varied from 0·6 to 18 grams, and the total weight administered to a single sheep varied from 6·4 to 864 grams ergot.

Table I summarizes the results.

Some of the experimental sheep were grazing grass throughout the course of dosing, others were kept penned and fed dry fodder. Some of the penned sheep ate very little of their ration and, in consequence, were dosed when in a state of partial starvation.

No one of these treatments caused a definitely greater susceptibility to poisoning by ergot, though there was some indication that ergot was rather more toxic when administered to partially starved animals. Very considerable differences in susceptibility to ergot poisoning occurred between individual sheep.

TABLE I.—EXPERIMENTAL DOSING OF RYE-GRASS ERGOT TO SHEEP

Sheep No.	Initial Weight.	Period of Experiment.	Total Ergot fed.	Doses.	Dose Rate.		Total Alkaloids in Ergot.	Symptoms.	Period between Final Dose and Slaughter.	Main Post-mortem Findings.
					Average.	Highest.				
	Kg.	Days.	g.		g.	g.	Per Cent.		Days.	
285	29	87	60	45	1·33	3·2	0·35	..	15	Slight pneumonia.
293	28	17	23·6	17	1·39	2·1	0·35	Ulceration of tip of tongue	4	Congestion rumen, abomasum, ileum, colon.
253	31	110	145	97	1·5	2·2	0·35	Slight diarrhœa ..	32	..
330	37	113	145	97	1·5	2·2	0·35	..	59	..
331	24	55	31	19	1·63	5·5	0·35	..	2	Slight pneumonia.
344	37	113	163	97	1·68	2·2	0·35	Dyspnœa ; salivation	28	Healed scars in rumen, subendocardial and renal hæmorrhages.
354	35	113	167	97	1·72	2·2	0·35	..	59	Healed scars in rumen.
436	37	113	234	97	2·41	4·2	0·35	..	59	Slight icterus.
342	37	113	232	96	2·42	4·2	0·35	..	1	..
345	29	2	6·4	2	3·2	3·2	0·35	Died	..	Inflammation of rumen and abomasum ; petechial hæm. pericardium.
248	29	288	864	238	3·63	5·5	0·35	..	2	..
274	29	15	44	9	4·9	5·5	0·35	Ulceration of tip of tongue. Died	..	Congestion abomasum, duodenum, petechial hæmorrhages epicardium diaphragm, renal cortex.
284	28	7	26·3	5	5·3	5·5	0·35	Diarrhœa ..	2	Severe inflammation and ulceration of abomasum and rumen, petech. hæm. renal cortex, spleen.
559	71	4	74	8	9·2	9·2*	0·22	..	1	Severe inflammation and ulceration of rumen and abomasum, congestion renal medulla.
477	48	30	197	21	9·4	11·5	0·22	..	1	..
543	70	7	87	9	9·7	18·4*	0·22	Died	..	Ulceration of abomasum and other parts of alimentary tract, petechial hæmorrhages in epicardium and endocardium.
548	41	30	150	30	5·0	5·0	Nil	..	1	..
635	26	30	150	30	5·0	5·0	Nil	..	1	..

* Twice in one day.

CLINICAL SYMPTOMS

Clinical symptoms were not marked or constant even in sheep subsequently shown to have well marked internal lesions.

Elevation of body temperature, dyspnœa, salivation, diarrhœa, depression, and loss of appetite occurred separately or in various combinations in a few cases. In two instances the tip of the tongue was affected, first becoming cyanosed and later ulcerated.

POST-MORTEM EXAMINATION

In six of the experimental animals it was necessary to allow a somewhat prolonged period to elapse between administration of the last dose of ergot and slaughter for post-mortem examination. This may have modified the picture at autopsy.

The changes observed in post-mortem examinations conducted soon after completion of dosing were somewhat inconstant. In a few cases the mucosa of the respiratory tract was congested, the regions affected being the pharynx, trachea, and bronchi. The pharyngeal and retropharyngeal lymph glands of some animals were also congested. In some cases petechial hæmorrhages were found, the most common locations being on the surfaces of the heart and in the kidneys.

In most cases there was a small excess of peritoneal, pleural, and pericardial fluids, and these fluids were sometimes tinged with blood.

Some livers were normal in appearance, others showed evidence of fatty infiltration or congestion with blood.

The most constant lesions were those affecting the alimentary tract. All stages from congestion to severe inflammation and ulceration of the mucosa were encountered. The more advanced changes were most common in the abomasum, but occurred also in the rumen: congestion and inflammation occurred in the duodenum, ileum, and colon, and petechial hæmorrhages were seen in the reticulum and at the bases of the lamellæ of the omasum. In a few cases areas of peritonitis affected the peritoneal surface of the alimentary tract, opposite to the regions where the mucosa was ulcerated.

Ulceration and necrosis of the tip of the tongue were observed in two cases.

Inflammation and ulceration of the mucosa of the alimentary tract appeared to be the most typical and definite lesion in ergot poisoning, and occurred in eight of the eighteen experimental animals.

PATHOLOGY

When it occurred, liver-damage was located at the centre of the lobule, where fatty infiltration, congestion, and necrosis occurred. In some instances retention of bile was noted.

In the kidneys there was sometimes congestion, sometimes small areas of hæmorrhage, and occasionally formation of cysts on the tubules and accumulation of albuminous material in the glomerular sac.

The affected walls of the alimentary tract showed all stages from congestion to necrosis and deep bacterial invasion of the walls.

HÆMATOLOGY

No changes were noted.

DISCUSSION

It is of some interest that the manifestations of poisoning by rye-grass ergot differ materially in sheep and bovines. In sheep the chief lesions are congestion, inflammation, or ulceration of mucous surfaces, particularly those of the alimentary tract; in bovines the extremities of limbs and of the tail are affected, first by an inflammatory reaction, ultimately by necrosis. That these differences are not due to variation in the poisonous properties of different samples of ergot is evident from the fact that characteristic lesions were produced in sheep 559 and 553 and in a cow* by the same sample of ergot. The extremities of the limbs of our experimental sheep were not affected even after prolonged dosing with relatively high levels of ergot.

It is possible that, in the sheep, the prominent lesions in the mucosa of the alimentary tract are due to local action of the ergot. The results of parenteral administration of ergotoxine to a sheep support this suggestion. 180 mg. ergotoxine ethanosulphonate were administered intromuscularly and intravenously in nine doses to a 24 kilogram sheep. The clinical symptoms produced were cyanosis, dyspnœa, salivation, pyrexia, anorexia, and loss of weight; on autopsy no lesions were found in any of the organs and the alimentary tract was normal.

Lesions in the sheep which can with certainty be ascribed to absorbed ergot poisons are congestion of the upper respiratory tract, necrosis of the tip of the tongue, and the presence of small hæmorrhages in some of the internal organs, serous membranes, and tissues.

Ergot poisoning in the sheep does not present a sufficiently characteristic picture to permit a diagnosis on the symptoms and lesions alone. It has, moreover, already been shown(2) in the case of cattle and pigs that even after a very large intake of ergot the demonstration of ergot alkaloids in organs or tissues is difficult or impossible. It is likely that the same result would be found with sheep, and thus chemical examination of organs cannot be expected to aid in diagnosis. To reach a positive diagnosis of ergot poisoning it would be necessary to demonstrate accessibility to ergot and absence of other causes of gastroenteritis.

No symptoms similar to those of rye-grass staggers occurred in any of the experimental sheep.

REFERENCES

(1) HOPKIRK, C. S. M. (1931): *Ann. Rept. N.Z. Dept. Agr.*, 53.
(2) CUNNINGHAM, I. J.; MCINTOSH, I. G.; and SWAN, J. B.: *N.Z. J. Sci. & Tech.*, **26**, 125.

---

* A full description of the lesions produced in the cow ("Brownie") appears in the next paper (p. 125).

THE NON-TOXICITY OF MILK AND MEAT FROM ERGOTIZED CATTLE

By I. J. CUNNINGHAM, I. G. McINTOSH, and J. B. SWAN, Department of Agriculture, Animal Research Station, Wallaceville

[*Received for publication, 7th July, 1944*]

Summary

A detailed investigation has led to the conclusion that milk or meat of cattle which ingest ergot with their fodder is not unsafe for human consumption.

This conclusion was reached from the results of chemical examinations and feeding trials with milk and body tissues of ergotized cows: no ergot alkaloids could be demonstrated in such materials, and white rats suffered no ill effects when fed them for long periods.

In the course of the work it was shown that large amounts of rye-grass ergot which contained no alkaloids did not induce symptoms of ergotism in a cow, while rye-grass ergot containing alkaloids quickly induced ergotism.

Pigs were shown to be resistant to poisoning with tall fescue ergot.

Rats were sensitive to ergot poisoning: large amounts in the ration were lethal, smaller amounts caused reduced growth-rate.

ERGOT is the name commonly applied to *Claviceps purpurea*, a fungus which will grow, when conditions are favourable, on the seed-heads of many species of grass and some species of cereals in New Zealand. Amongst the grasses frequently infected are perennial rye-grass, tall fescue, marram-grass, and cocksfoot, while of the cereals barley is the most susceptible. A closely-related fungus, *Claviceps paspali*, infects paspalum, and the name ergot is sometimes applied to this fungus. For the purpose of the present article, however, the term ergot is restricted to *Claviceps purpurea*.

Ergot is most conspicuous in the form of hard, black banana-shaped bodies, the sclerotia, which are seen on the ripening seed-head of the host-plant. The sclerotia constitute the stage of maturity and also a resting-phase in the life-cycle of *Claviceps*; they mature at approximately the same time as the seed of the host-plant, and either are harvested with it or drop to the ground, where they remain dormant throughout the winter. A period of winter cold followed by spring warmth initiates germination of some of the sclerotia on the ground. Spores are liberated and are distributed by wind at about the period when the host-plant is flowering. Those spores which alight on an open flower develop, and the resulting mycelia enter the growing ovum. A second type of spore is produced during this period and becomes suspended in a sticky "honey-dew," which is exuded from the infected flower. Spread of this second type of spore is by the washing action of rain, by contact of honey-dew with neighbouring flowers, or through carriage of honey-dew by insects from flower to flower.

Mycelia entering the ovum of an infected flower multiply, until, finally, the ovum is replaced by a compact mass which matures to form the sclerotium. It is to the sclerotia of *Claviceps* that the term ergot is popularly applied.

Preparations of ergot have important uses in medicine, in particular for the control of post-partum hæmorrhage. Ergot in large doses, however, is known to be toxic, humans and domestic animals both being susceptible to ergot poisoning.

In humans two types of ergotism are recognized, convulsive and gangrenous; in animals the gangrenous type occurs. The etiology of convulsive ergotism is not fully understood, but gangrenous ergotism is recognized as the result of constriction of the muscular coat of the smaller blood-vessels, with consequent restriction of nutrient blood-supply. Failure

of nutrition results in death, and possibly even sloughing of the affected region. Parts usually affected are, in humans, the terminal portions of the limbs, and, in cattle, the hooves and the tip of the tail.

Since ergot is poisonous to humans as well as to domestic animals it is important to know whether there can be any transmission of toxic principles to humans who ingest milk or flesh from animals which have been exposed to the risk of consuming ergot in their fodder. An experimental investigation of such a possibility forms the subject of this paper.

The design of the investigation was to feed ergot to milking-cows until gross symptoms of ergotism developed. Milk secreted during the period in which the cows were dosed with ergot, and body tissues collected from the cows after slaughter, were tested for the presence of ergot toxins by chemical examination and by feeding experiments on white rats.

Ergot from tall fescue grass (*Festuca arundinaceae*) and ergot from perennial rye-grass (*Lolium perenne* L.) were employed in the investigation, these being the species most commonly accessible to domestic cattle in New Zealand.

It is widely accepted that the lævorotatory water-insoluble alkaloids, especially ergotoxine and ergotamine, are the principles in ergot responsible for the phenomenon of gangrene. Evidence in support of this point has been summarized earlier(1), and more evidence is adduced in this paper. Determinations of alkaloid content were therefore made on the samples of ergot employed in feeding-tests. As a matter of interest alkaloid contents were also determined in a number of samples of pure specimens of ergot collected from different species of grass or cereals. The results are given in Table I. The conventional procedure has been adopted of expressing the total alkaloids, and the water-insoluble alkaloids as ergotoxine and the water-soluble fraction as ergometrine.

TABLE I.—ALKALOID CONTENTS OF ERGOT* SCLEROTIA FROM DIFFERENT SPECIES (PERCENTAGE OF AIR-DRY SAMPLE)

Sample No.	Species.	Date received.	Total as Ergotoxine.	Water Insoluble as Ergotoxine.	Water Soluble as Ergometrine.	Analytical Method.
1	Rye-grass (*Lolium perenne*) ..	24/8/41	Nil	..	..	..
2	,, ..	9/9/41	Nil	..	..	..
3	,, ..	10/12/41	0·22	0·11	0·06	..
4	,, ..	—/3/42	0·31	0·22	0·047	..
5	,, ..	18/3/42	0·34	0·21	0·068	..
6	,, ..	23/4/40	0·36	..	..	BP
7	,, ..	22/5/43	0·44	0·42	..	*
8	Tall fescue (*Festuca arundinaceae*)	4/6/41	0·24	..	..	BP
9	Ditto	24/8/41	0·31	..	0·006	..
10	,, ...	8/9/41	0·35	..	..	..
11	,, ...	8/9/41	0·39	..	..	..
12	Marram-grass (*Psamma arenaria*)	2/6/42	0·31	0·24	0·036	..
13	Cocksfoot (*Dactylis glomerata*)	—/3/42	0·53	0·21	0·17	..
14	Crested dogstail (*Cynosurus cristatus*)	—/3/42	0·23	0·16	0·034	..
15	Tussock (*Poa* spp.)	18/12/42	Nil	..	..	..
16	*Danthonia raoulii*	2/6/42	Traces	..	..	..
17	*Danthonia florescens* ..	2/6/42	0·04	..	..	..
18	Wheat (*Triticum sativum*) ..	2/6/42	0·63	0·37	0·14	..
19	Barley (*Hordeum sativum*) ..	2/6/42	Traces only	..	..	..
20	Mixed	..	0·37	0·25	0·06	*
21	Mixed	..	0·57	0·50	0·04	*

In all but five instances the method of analysis was that of Hampshire and Page(2). In two instances, denoted BP in the final column, the method was that described in the British Pharmacopœia(3); in three instances, denoted by an asterisk in the final column, the total alkaloids were determined after extraction from the marc by Hampshire and Page's method, but the water-soluble fraction was separated by the method of Allport and Jones(4).

In some instances a figure has been given for water-soluble alkaloids. This figure was obtained by the procedures mentioned above, but separation of the water-soluble fraction was not as rapid or as complete as is claimed for the same methods when applied to European ergot. With Hampshire and Page's method separation was neither sharp nor definite, and at least twenty extractions with water were necessary before the final aqueous extract gave no colour with p-dimethylaminobenzaldehyde; with the modification devised by Allport and Jones separation was sharp and definite, but at least eight to ten extractions were necessary to obtain complete separation. Not more than five extractions are necessary to effect complete separation in European ergots.

Some doubt, therefore, exists whether the water-soluble material separated by the methods employed was, in fact, ergometrine. The observations made on the abnormal solubility in water, and the results obtained by application of conventional methods are included here to indicate that the alkaloids of New Zealand ergot merit some detailed chemical investigation.

Because of the doubt associated with the figures for water-soluble alkaloids, comment is restricted to the results for total alkaloids. Rye-grass and tall fescue ergots are the only strains of which any number of different samples were available. The absence of alkaloids from some samples of rye-grass ergot was of interest. The method employed was capable of detecting 0·005 mg. of alkaloids in 10 g. ergot; failure to demonstrate alkaloids, therefore, represents their virtual absence. Comparatively small variation was found in different tall fescue ergots. The general order of alkaloid content is similar to that found in good European ergots.

Interesting features of the remaining results are the low alkaloid contents of the danthonia, tussock, and barley ergots, and the high contents in wheat and cocksfoot ergots.

CATTLE-FEEDING EXPERIMENTS

Tall Fescue Ergot.—Finely-ground ergot of tall fescue was administered to a cow, "Babs," daily from 30/5/41 to 8/9/41. Each day's dose was suspended in water and administered by drenching.

A pure sample of ergot was employed, the total alkaloid content of which was 0·24 per cent. (sample No. 8, Table I). The total weight dosed was 3,415 g.

Details of dosing are shown in Table II.

TABLE II.—TALL FESCUE ERGOT DOSED TO "BABS"

Grams of Ergot per Day.	Period (Days).	Dates.	Symptoms.
5	53	30/5/41 to 21/7/41	None.
50	35	22/7/41 to 25/8/41	None.
100	14	26/8/41 to 8/9/41	Lameness, 5/9/41.

Lameness first developed on 5/9/41 in the right hind limb and was accompanied by swelling of the hock, and swelling and marked tenderness of the right hind fetlock. The swelling in the fetlock increased daily, but tenderness decreased.

By 9/9/41 both hocks were swollen and all four fetlocks were also swollen and tender.

On 10/9/41 sensory perception was absent from skin of the lower portion of both hind fetlocks.

By 11/9/41 an indented line, which had appeared in the skin on the flexor aspects of the fetlock joints of both hind limbs, had extended round the sides and to the extensor aspect of the joints.

By 12/9/41 the fetlocks of both hind limbs were cold, and sensory perception was absent; the left fore fetlock was at this time hot and sensitive to a touch.

By 16/9/41, eight days after cessation of dosing, swelling had almost disappeared in the left fore fetlock and the joint was resuming a normal appearance. Both hind fetlocks were cold and the skin was dry and hard.

A high body-temperature and increased pulse and respiration rates accompanied the lameness. For example, on 11/9/41 body temperature was 104·6° F., pulse rate 150 per minute, and respiration rate 110 per minute; on 15/9/41 body temperature was 103·2° F., pulse rate 140 per minute, and respiration rate 70 per minute.

The cow was slaughtered on 16/9/41.

On post-mortem examination no abnormalities were noted in the alimentary tract except for a large blood-clot situated in the mesentery supporting the rectum. The hæmorrhage was due to rupture of a small artery. In the liver numerous small hæmorrhages were found on the surface and throughout the substance of the organ. Each hæmorrhage was approximately ¼ in. in diameter, and approximately 2 in. of normal tissue separated one hæmorrhagic spot from the next.

The right fore limb was normal.

In the left fore limb the skin was normal. The subcutaneous tissue over the fetlock joint was œdematous, but there was no hæmorrhage.

In both hind limbs the skin was healthy down to the indented line noted ante-mortem. Here there was a sharp transition to cyanotic hardened skin, the surface of which was encrusted with dried exudate. There were extensive subcutaneous hæmorrhages from the hock downwards.

The skin of the terminal 2 in. of the tail was cyanosed and hardened; subcutaneous hæmorrhages were found on the last 6 in.

Sections of liver and of skin from hind limbs and tail were examined by Dr. C. S. M. Hopkirk, who reported as follows:—

Liver.—Throughout the section the central vein and sinusoids were congested and dilated. Arising from this, in some places lagoon hæmorrhages had occurred, and where these had been in existence for any length of time necrosis of parenchyma cells had taken place and fibrous tissue had been laid down giving the appearance of multilocular blood cysts.

Kidney.—Congestion of capillaries of medulla only.

Skin.—A line of demarcation between normal and damaged tissue was evident though some congestion of capillaries had occurred in the "normal" tissue near the line of demarcation. The subcutis of the damaged tissue showed a large hæmorrhage; in the capillaries near the dermis, stasis of blood followed by breakdown of red blood corpuscles had occurred. The dermis and epidermis were tough and necrotic, and the epidermis had, in places, been infiltrated with round cells with formation of a dry scab. Gram staining gave no evidence of infection with gram positive organisms in the area.

Examination of sections suggests two possibilities of cause of skin lesions:—

(1) That subcutaneous hæmorrhage had cut off blood-supply:

(2) That stasis of blood had occurred in reticular areas of the skin.

Rye-grass Ergot.—Pure specimens of rye-grass ergot were not available for feeding experiments. It was necessary, therefore, to feed residues left from commercial cleaning of rye-grass seed.

A sample of rye-grass seed containing 7 per cent. ergot sclerotia was fed to a cow "Ailsa." Chemical examination showed that this ergot contained no alkaloids (Sample No. 1, Table I).

For administration the seed-ergot mixture was made into a mash with bran and fed daily. Details of feeding are shown in Table III.

TABLE III.—RYE-GRASS ERGOT FED TO "AILSA"

Grams of Ergot per Day.	Weight of Seed-ergot Mixture.	Period. (Days).	Dates.	Symptoms.
	Grams.			
4·2	60	70	25/6/41 to 2/9/41 ..	None.
17·5	250	5	3/9/41 to 7/9/41 ..	None.
35	500	10	8/9/41 to 17/9/41 ..	None.
70	1,000	22	18/9/41 to 9/10/41 ..	None.
98	1,400	25	10/10/41 to 3/11/41 ..	None.

"Ailsa" was slaughtered on 10/11/41. Post-mortem examination showed no abnormality.

Details of this experiment are included because of the interesting feature that no toxic effects were induced by rye-grass ergot containing no ergot alkaloids. A total of about 4,700 g. ergot was fed in a period of 132 days.

The absence of toxic symptoms in this experiment is in marked contrast to the rapid onset of symptoms in another cow ("Brownie"), who was fed rye-grass ergot containing 0·31 per cent. total alkaloids.

For a second feeding experiment a sample of rye-grass seed containing 2·26 per cent. ergot sclerotia was available. This ergot contained 0·31 per cent. total alkaloids (Sample No. 4, Table I). It was fed to a cow "Brownie." Attempts were made to feed this seed as a mash made with molasses and bran. Two doses of 2·5 kg. seed were consumed on 24/2/42 and 25/2/42, but after this the mash was refused. Subsequently the seed-ergot mixture was finely ground, suspended in water and administered by stomach tube. A total of 1,638 g. sclerotia was fed. Details of dosage are shown in Table IV.

TABLE IV.—RYE-GRASS ERGOT DOSED TO "BROWNIE"

Grams Ergot per Day.	Weight Seed-ergot Mixture.	Period. (Days).	Dates.	Symptoms.
	Grams.			
56·5	2,500	2	24/2/42 to 25/2/42 ..	None.
27·1	1,200	1	12/3/42	None.
56·5	2,500	21	13/3/42 to 2/4/42 ..	Lameness, 27/3/42.
28·3	1,250	11	8/4/42 to 18/4/42 ..	..

Lameness first developed on 27/3/42, when the fetlocks of left fore and left hind legs were swollen and tender. On 28/3/42 the right hind fetlock was also swollen; on 30/3/42 there was marked salivation and frothing at the mouth.

Lameness was so marked that dosing was suspended between 3/4/42 and 7/4/42 as the cow could not be driven into the bail.

On 8/4/42 an indented line appeared round the left fore and both hind fetlocks. The tail was cyanotic and œdematous over its terminal 2 in.

By 17/4/42 the horn of the accessory digits of the left hind foot sloughed and the right fore fetlock was swollen. On 20/4/42 the horn of the left hind foot had sloughed and the os pedis had penetrated the soft tissue of the hoof.

An increase in body temperature, pulse rate, and respiration rate occurred similar to that already recorded for "Babs."

"Brownie" was slaughtered on 20/4/42. Post-mortem examination revealed lesions only in the liver, legs, and tail. In the liver extensive yellow patches occurred over most of the left lobe and all of the papillary lobe. Lesions in the legs and tail were similar to those already described in "Babs."

Sections of liver were examined by Dr. C. S. M. Hopkirk, who reported as follows:—

Liver.—Sections from the apparently normal area showed fatty infiltration of central cells.

Sections taken from yellow areas showed accumulations of bile in sinusoids, reticulo-endothelial cells, and central veins.

The milk secreted by "Babs" and by "Brownie" over the whole period during which they were dosed with ergot was collected and fed to white rats. Samples of muscle from "Babs" and of muscle and viscera from "Brownie" were collected immediately after slaughter and fed fresh or after freezing or drying to various animals.

The results of these experiments will be detailed later.

SYMPTOMS OF ERGOTISM IN PIGS AND WHITE RATS

It was desirable, as one basis for testing whether toxic principles of ergot were excreted in milk or stored in tissue, to have a test animal which was known to be susceptible to poisoning by ergot. Pigs and white rats were the most convenient experimental animals for this purpose since they would readily consume milk or flesh and since their growth and development on normal milk and normal flesh are well understood. Preliminary feeding experiments were therefore carried out with diets to which known amounts of ergot were added to determine the reactions of these animals to ingestion of ergot.

Pigs.—Pure strains of ergot were not available for pig-feeding experiments. The material employed was a mixture of sclerotia collected from different species of grass, the greater part of the ergot being from tall fescue grass.

Pig 1, body-weight, 25 kg., was dosed by stomach tube with ergot sclerotia which contained 0·37 per cent. total alkaloids (Sample No. 20, Table I). Seven doses of 100 g. ground ergot were administered in a period of eight days, two doses being given on the last day.

Slight tenderness on all feet was noticed on the fifth day, but this cleared up.

The pig was killed on the ninth day.

Post-mortem examination revealed no abnormalities, and histological examination showed that liver, spleen, kidney, and stomach wall were normal.

Pig 2, whose body-weight at commencement was 20 kg., was dosed by stomach tube with ergot which contained 0·57 per cent. total alkaloids (Sample No. 21, Table I).

Forty-three doses were administered in seventy-one days between 25/11/42 and 3/2/43, the total weight of ergot given being 1,760 g.

The details of dosing were as follows :—

Twelve doses of 20 g. each in first sixteen days.
Eighteen doses of 40 g. each in next thirty-two days.
Twelve doses of 60 g. each in next twenty-two days.
One dose of 80 g. on last day.

After thirty-six days' treatment—*i.e.*, on 30/12/42—there were signs of tenderness in walking, but this symptom rapidly passed off.

The animal was slaughtered on the day following the last dose. At autopsy no macroscopic or microscopic abnormality was found.

Samples of muscle and visceral organs were collected from both pigs immediately after slaughter for determination of ergot alkaloids.

It was evident that little effect could be produced in the pig even by massive doses of ergot. The pig, therefore, was considered not suitable as an indicator of the presence of ergot toxins in its food.

Rats.—Two experiments were carried out. In the first, rats were fed diets to which tall fescue ergot was added ; in the second the diets fed contained rye-grass ergot.

The mixture used as a basal ration was similar to the ordinary stock ration and consisted of cereals (55), meat-meal (13), dried milk (16), wheat-germ (8), dried yeast (2), rice polishings (2), cod-liver oil (2), calcium carbonate (1½), and sodium chloride (½).

Appropriate quantities of the ration were made up by mixing with freshly-ground ergot sclerotia three times per week.

Young Wistar strain albino rats from the Station colony were employed as experimental animals. They were placed on the experimental rations immediately after weaning, and observations were made on body-weight and general health for an eight weeks' feeding-period.

In the tall fescue ergot experiment four groups of ten rats were fed rations containing 0, 0·1, 1·0, and 3·0 per cent. of ergot. In the perennial rye-grass ergot experiment five groups of six rats were fed rations containing 0, 0·1, 0·5, 1·0, and 3·0 per cent. ergot.

Detailed results are shown in Tables V and VI.

TABLE V.—BODY-WEIGHT OF RATS FED TALL FESCUE ERGOT (TOTAL ALKALOIDS, 0·24 PER CENT.), (TEN RATS PER GROUP)

Weeks on Diet ..	..	0.	1.	2.	3.	4.	5.	6.	7.	8.
Group No.	Ergot in Diet, per Cent.	Average Body-weight, in Grams.								
I ..	0	39	57	81	94	106	122	129	130	161
II ..	0·1	40	46	57	70	84	102	107	114	140
III ..	1·0	40	47	58	64	76	90	96	103	118
IV ..	3·0	40	37(6)	36(3)	All dead.	..	..	..	..	..

TABLE VI.—BODY-WEIGHT OF RATS FED RYE-GRASS ERGOT (TOTAL ALKALOIDS, 0·44 PER CENT.), (SIX RATS PER GROUP)

Weeks on Diet ..		0.	1.	2.	3.	4.	5.	6.	7.	8.
Group No.	Ergot in Diet, per Cent.	Average Body-weight, in Grams.								
I ..	0	39	50	78	107	128	154	172	190	204
II ..	0·1	39	56	75	102	132	157	176	192	200
III ..	0·5	39	45	52	72	91	113	131	147	163
IV ..	1·0	37	39	40(3)	All dead.	..	..		..	..
V ..	3·0	41	36(2)	All dead.	..	..	..	..	..	..

The figures for body-weight in Tables V and VI represent the mean for ten and six animals respectively, except in those cases where a figure in brackets follows the body-weight figure. This bracketed figure represents the number of surviving animals.

Diets containing 3 per cent. tall fescue ergot or 1 per cent. or more rye-grass ergot were lethal. All rats fed these rations failed to grow, and all died in less than three weeks. The only ante-mortem symptoms displayed were progressive emaciation and dullness; post-mortem examinations revealed gastroenteritis, emaciation, and absence of all deposits of body-fat.

The growth-rate of rats fed diets containing 0·1 and 1·0 per cent. tall fescue ergot was materially retarded in comparison with that of control animals. The difference in growth was not due to difference in food intake since food-consumption records showed that groups I, II, and III, fed ration containing 0, 0·1, and 1·0 per cent., ate approximately the same total weight of food in eight weeks.

In rats fed rations containing 0·5 per cent. rye-grass ergot growth-rate was also retarded, and this reduced rate of growth was again not associated with reduced food intake.

At the end of the feeding-period the control rats and the rats fed 0·1 and 1 per cent. tall fescue ergot and those fed 0·5 per cent. rye-grass ergot were slaughtered and post-mortem examinations made; no abnormalities were found.

These experiments showed that under controlled conditions the white rat could be employed as a moderately sensitive indicator of the presence of ergot in the ration. Relatively large amounts of ergot were lethal and small amounts caused a material reduction in rate of growth.

These reactions of the white rat to ergot ingestion were employed in the present work as one indicator of the presence of ergot toxins in the milk and tissues of the experimental cows dosed with ergot. The use of the white rat in this manner had the advantage that it provided an indication not only of the possible direct transmission or storage of ergot toxins, but also of the presence of harmful products formed during digestion or metabolism of ergot by the cow.

FEEDING MILK OF ERGOTIZED COWS TO RATS

Milk from the cows, "Babs" and "Brownie," in which symptoms of ergotism were induced by feeding ergot sclerotia, was fed to rats. Details of the growth-rates of these rats and of the growth-rates of rats fed normal milk are shown in Table VII. Rats were started on the experiment directly after weaning, and the sole ration was fresh milk to which traces of iron, copper, manganese, and iodine were added.

Milk-collection commenced at approximately the same time as ergot feeding commenced, and part of each day's collection was fed fresh to rats on the day of milking. New groups of young rats were introduced into the experiment at different times during the course of treatment of the cows. This provided against the remote possibility that the original rats, being fed on milk with a possibly gradually increasing content of toxin, might have developed a tolerance by the time the end of the experiment was approaching and when the milk might reasonably be anticipated to be most toxic.

TABLE VII.—BODY-WEIGHTS AND FOOD-CONSUMPTION OF RATS FED NORMAL MILK AND MILK FROM ERGOTIZED COWS

Source of Milk.	Date Rat Feeding commenced.	Number of Rats.	Ergot consumed by Cow during Period Rats fed Milk.	Average Weekly Body-weight of Rats during Feeding Experiment.											Weeks on Experiment.	Total Milk consumed.
				0.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.		
Fescue Ergot																
			Grams.													Grams.
Babs ..	3/6/41	8	1.295	40	56	82	104	123	142	158	168	176	183	197	10	33,000
" ..	4/8/41	6	1.700	40	69	91	115	130	..	..	..	..	..	..	4	8,000
" ..	27/8/41	3	1,300	40	55	77	88	..	..	..	..	..	..	..	4	2,300
Normal ..	3/6/41	6	Nil	40	49	68	79	88	108	129	141	152	162	174	10	22,000
Rye-grass Ergot																
Brownie ..	26/2/42	6	1,440	44	52	66	82	95	115	142	153	..	..	..	7	14,300
" ..	31/3/42	4	481	47	63	77	99	..	..	..	..	..	..	..	3	
Normal ..	26/2/42	6	Nil	44	49	61	73	92	109	134	145	..	..	..	7	13,300
" ..	31/3/42	3	Nil	45	63	81	100	..	..	..	..	..	..	..	3	

The results in Table VII show clearly that no adverse effect on growth-rate of rats occurred when their sole diet was milk from cows fed tall fescue or rye-grass ergot. This was true of rats fed milk produced by the cows when low doses of ergot were being administered, and also of rats commenced near the time when the cows developed clinical symptoms of ergotism.

The physical condition of the rats was good throughout the experiment, and autopsy made at the end of the feeding-period revealed no abnormality.

It can be concluded that either no ergot toxins or, at the most, negligible amounts, were directly transmitted to the milk. It can be concluded also that there were no harmful products of digestion or metabolism of ergot secreted in milk.

FEEDING FLESH AND VISCERAL ORGANS FROM ERGOTIZED COWS

Fescue Ergot Cow.—After slaughter, several pounds of muscle from "Babs" were fed to a pregnant cat, to pregnant rats and to dogs, but no records of consumption were kept. No adverse symptoms were produced in any of the animals.

Rye-grass Ergot Cow.—Samples of muscle and "viscera" were collected from "Brownie" immediately after slaughter and were preserved for feeding experiment. The muscle was sampled from different regions of the body; the "viscera" included tongue, spleen, kidney, heart, and liver.

The samples were preserved by two different methods—one part was dried and ground and stored in this condition, the second part was minced and stored in a frozen state, portions being thawed out each day for incorporation in rations. Dried and frozen materials were fed separately.

Four groups of six rats each were fed for six weeks the rations set out in Table VIII, the stock ration being similar to that already described. The table shows also the average daily consumption of muscle or viscera and the average weight gain over the period of six weeks feeding.

TABLE VIII.—WEIGHT-GAIN OF RATS FED TISSUES FROM "BROWNIE"

Number of Rats.	Ration.	Muscle or Viscera.		Average Weights of Rats.		
		Percentage in Ration.	Average Weight consumed per Rat Daily.	At Commencement.	After Six Weeks.	Gain.
			Grams.	Grams.	Grams.	Grams
6	Stock rations, plus dried muscle	20	3·15	48	237	189
6	Stock ration, plus frozen muscle	20	4·58	50	216	166
6	Stock ration, plus dried viscera	20	3·5	49	226	177
6	Stock ration, plus frozen viscera	20	4·2	45	201	156

The figures in the last column of Table VIII should be compared with the average gain in weight of stock rats in this Station's colony; this is 125 g. in the first six weeks after weaning.

It is evident that inclusion of frozen or dried muscle or viscera in their ration had no ill effect on growth-rate in rats. No abnormalities developed in rats during life and all were normal at autopsy.

It was concluded that there was no storage of ergot toxins, or of any toxic products of metabolism, in flesh or viscera of cows fed ergot sclerotia.

ALKALOID CONTENT OF MILK AND BODY TISSUES OF ANIMALS FED ERGOT SCLEROTIA

Milk.—Four hundred and sixty-two grams of milk collected from "Brownie" over the period 4–17/4/42—that is, during the period when acute symptoms of ergotism were developing—were analysed as one sample for ergot alkaloids. The result was negative.

Body Tissues.—Muscle and "viscera" were examined chemically and biologically for ergot alkaloids. The samples were collected as soon as possible after slaughter, minced and placed in 96 per cent. alcohol. Extraction procedure was based on the method described by Kluge(5), chemical assay was by the colorimetric procedure using p-dimethylaminobenzaldehyde, biological assay was by the cocks comb method.

Eleven hundred grams muscle and the same weight of viscera (liver, kidney, spleen, heart, tongue) from "Brownie" were extracted. Chemical and biological tests for ergot alkaloids were negative.

The chemical data thus agree with the feeding tests on rats in demonstrating the absence of ergot toxins in milk or body tissues of cows fed rye-grass ergot.

Chemical tests were also made on muscle and viscera (liver, kidney, spleen, heart) of pigs 1 and 2, to which large quantities of ergot sclerotia were dosed in the manner described earlier in this paper. The results are summarized in Table IX.

TABLE IX.—ALKALOIDS IN THE TISSUES OF PIGS FED ERGOT

Pig.	Weight Ergot fed.	Period of Feeding.	Total Ergot Alkaloids fed.	Alkaloid Content.	
				Muscle.	Viscera.
	Grams.	Days.	Grams.		
1 ..	700	8	2·59	Nil in 1,800 g.	Less than 0·01 mg. in 900 g.
2 ..	1,760	71	10·03	Nil in 1,000 g.	0·02 mg. in 900 g.

In pigs, therefore, as in cows, there was no accumulation of ergot alkaloid in tissues after large quantities of the alkaloid had been ingested.

DISCUSSION

In considering whether toxic principles of ergot can be excreted in the milk or stored in the tissues of cattle it is pertinent to make some comment on the accessibility of ergot to stock in New Zealand.

The extent to which New Zealand pasture grasses may become infected with ergot is not known with certainty. The incidence of ergotism in cattle may, however, be mentioned as an indication of their exposure to the risk of consuming ergot. Very few cases of ergotism are, in fact, reported; generally speaking, of those which are reported most occur amongst cattle which have been grazing on tall fescue grass. One recent case is known to the authors in cows which were fed ergotized rye-grass hay.

Many of the cattle grazed on tall fescue grass or fed hay are in a " store " condition—that is, they are neither lactating nor in the process of fattening for slaughter. It is therefore unlikely that the cattle to which ergot is most accessible would make any significant contribution to the nation's milk or meat supply.

This might indicate that it is immaterial whether ergot alkaloids can appear in milk or in edible tissues. However, the possibility cannot be entirely dismissed that cattle which are actually producing milk or meat may ingest small amounts of ergot, insufficient to produce clinical symptoms of ergotism, and transmit toxins to the milk or edible tissues.

No estimate can be made of the extent to which cattle may ingest sub-toxic doses of ergot, but it is apparent, from a consideration of the life-history of ergot, that the circumstance would extend over a short season and be confined to those animals grazed on infected grasses in the summer or fed hay made from infected grass.

In the work described above it has been shown that, even under the most favourable conditions of ergot intake, no evidence can be found of the transmission of ergot toxins to milk or body tissues.

Cows were fed ergot of tall fescue grass and ergot of rye-grass in sufficiently large amounts and for periods long enough to produce clinical symptoms of ergotism. This procedure ensured that the experimental cows possessed no individual resistance to ergot and ensured also that they became, as far as possible, saturated with ergot. Even under these circumstances it

was not possible to demonstrate chemically the presence of ergot alkaloids in milk or body tissues, and feeding tests with rats showed that neither the milk nor the body tissues contained any substances inimical to growth or health of the rats. The feeding experiments with rats provided a test not only for the ergot alkaloids, but also for the presence of any harmful products which might be formed during digestion and metabolism of ergot.

It is, in the opinion of the authors, reasonable to interpret the data presented as indicating that there is no risk to human health from the consumption of meat or milk derived from cattle which may have access to ergot in their fodder.

ACKNOWLEDGMENTS

The authors wish to record their indebtedness to Dr. C. S. M. Hopkirk, of this Station, who made the pathological examinations recorded in this paper, to Mr. J. E. Bell, Fields Division, Department of Agriculture, who supplied some of the pure strains of ergot, and to the Abraham Seed and Produce Co., Ltd., Palmerston North, who donated large quantities of seed cleanings containing rye-grass ergot.

REFERENCES

(1) CUNNINGHAM, I. J. (1941): *N.Z. J. Sci. & Tech.*, *23*, 138A.
(2) HAMPSHIRE, C. H., and PAGE, G. R. (1936): *Quart. J. Pharm.*, *9*, 60.
(3) British Pharmacopœia (1932): Constable and Company, Ltd., London.
(4) ALLPORT, N. L., and JONES, N. R. (1941): *Quart. J. Pharm.*, *14*, 106.
(5) KLUGE, H. (1934): *Z. Untersuch. Lebensm.*, *68*, 645. Abstract from *Analyst* (1935), *60*, 266.

A BASIC SCHEME FOR LAND CLASSIFICATION

By L. I. GRANGE, Soil Survey Division, Department of Scientific and Industrial Research

[*Received for publication, 10th July, 1944*]

A SATISFACTORY method for the classification of land that will have value in considering the numerous problems in connection with its utilization has been sought for several years in many countries. The purpose of the present article is to outline the basic method of approach that has been followed out in the North Island of New Zealand.

A carefully-constructed soil map is believed to be the foundation for land classification. The planning of such a map of the North Island was considerably aided by the fact that the Division had already gained experience of the main groups of soils from detailed mapping in several localities(1). Besides the districts on which publications have been issued, much of North Auckland and Hawke's Bay had been covered by fairly-detailed surveys. Mapping for the whole Island was undertaken on Lands and Survey lithos 1 mile to an inch, and on the available topographic maps on the same scale. Wherever possible, use was made of vertical air photographs. In order that the soils throughout the Island could be related, the genetic classification was employed. In the field the pedologist first recognized the genetic group to which a soil belonged, then the stage

within the group, and lastly the soil series and type. The genetic groups are the broad divisions of soils, which follow, with a few exceptions, the groupings used in other parts of the world. The genetic groups, each of which has a number of soil characteristics in common, separated out during the North Island survey are—

(1) *Recent Soils.*—These are derived from recent deposits of alluvium or of volcanic ash. They are not leached and are in general of high fertility :

(2) *Rendzina Soils.*—These are lime-humus soils developed on limestone rock :

(3) *Yellow-grey Loams.*—They are derived from calcareous mudstone and argillaceous sandstone under a rainfall between 35 in. and 45 in. Generally their only deficiency is phosphate :

(4) *Podzols.*—A well-developed podzol is characterized by a dark-grey humus-bearing topsoil resting on a very light ash-grey layer which in turn rests on a brown iron-cemented layer. In places an horizon of humus-bearing soil is interposed between the grey layer and the iron-bearing layer. In the North Island there are two main divisions of podzols—one derived from ancient volcanic-ash deposits and the other from sedimentary and massive acid igneous rocks :

(5) *Brown Loams.*—They contain three main sub-groups—the yellow-brown loams derived from andesitic volcanic ash, the brown granular clays derived from andesite and dolerite rocks, and the red-brown loams derived from basalt. They are all high in iron oxide and alumina and are friable soils, easily worked :

(6) *Meadow Soils.*—These develop under the influence of high level of ground-water :

(7) *Organic Soils.*—These are the peaty soils :

(8) *Saline Soils.*—These contain soluble salts derived from sea-water. Their colour is blue-grey and their structure is poor :

(9) *Skeletal Soils.*—They cover the steep hill country and are for the most part shallow soils closely related to the parent rock :

(10) *Mountain Soils.*—These take in the steep and broken country more than 3,500 ft. above sea-level.

Most of the groups are divided into stages—young, immature, semi-mature, and mature. A soil in the young stage is but little leached, whereas one in the mature stage has been extremely leached of several of its chemical constituents, including its plant-foods, by the prolonged action of downward-percolating waters. For instance, the young and immature podzols have brownish-yellow subsoils, the semi-mature having a grey and brown flecked horizon below the topsoil, and the mature a well-developed light-grey horizon. These stages mark a progressive leaching of iron oxide and alumina from the upper horizons. The leaching, as stated, removes plant-foods, so that the young soils are the most fertile and the mature the least fertile. Taking the podzol again as an example, in the young stage it requires phosphate and little or no lime top-dressing, whereas in the mature stage high amounts of phosphate and of lime are needed. All the soils in any one stage of a group are not exactly similar, and the differences are allowed for by dividing the stages into series and types.

While marking out soil types, a number of points relating to them are noted. These include parent material, rainfall, vegetation, topography, profile, fertility, the present use of the soil, carrying-capacity, top-dressing practice, and the amount of erosion. The pedologist collects samples of the soil horizons of each soil type for chemical analysis of plant nutrients.

Following the field mapping, the pedologists and chemists met together and drew up a common classification for the soils of the Island. A legend of the soil types, together with all the information mentioned above, including chemical analyses, was drawn up. The soil map on a scale of 4 miles to an inch was then drafted.

The soil map in itself has a limited practical use. There is information in the legend on each of the soil types—somewhat more than five hundred—but working from this no picture is obtained of conditions over the whole of the North Island, nor is the information linked with that obtained from other investigations. The next stage is to produce from it single-factor maps each depicting one particular land use. These are simple maps each with only half a dozen or so classes, compared with the numerous subdivisions on the soil map. That such maps can be drawn is obvious when it is remembered the variety of information recorded in the legend on each soil type. Plant nutrients determined in the soil include phosphate, potash, lime, magnesia, nitrogen, and carbon, and as well the acidity of the soil is recorded. This means that a single-factor map for any one of these nutrients can be made. The first single-factor map to be compiled was that for lime, and for this purpose the Division co-operated with the Fields Division of the Department of Agriculture. By uniting soil information with actual responses obtained in trials by the Fields Division a new map embodying all data possessed by these Departments was obtained.

The legend for this map is :—

No. 1	Little or no lime response.
No. 2	Slight to moderate lime response. Initial dressing, ½ ton an acre ; annual, 2 cwt. to 4 cwt.
No. 3	Good lime response. Initial dressing, ¾ ton to 1 ton an acre ; annual, 4 cwt. to 6 cwt.
No. 4	Strong lime response. Initial, more than 1 ton an acre ; annual, 6 cwt. to 7 cwt.

This map can be used as a basis for advice to farmers on liming. The areas of the four classes of lime requirements were measured, and the position may be summarized as follows :—

Of the ploughable land that is being farmed—*i.e.*, 6,662,000 acres*—3,052,000 acres require lime, and the remainder—3,610,000 acres—do not. Assuming that the ploughable land deficient in lime needed an initial dressing, then 1,993,000 tons of lime would be required for this purpose in the first year, and when all land had received its initial dressing 870,000 tons would be required annually. The total output of lime in 1941 was 269,000 tons. Even assuming that all farms had had their initial heavy dressings, there is room for more than three times the present production of lime. Allowing for some initial dressings, it is safe to say that lime output could be at least quadrupled. The position is conservatively stated, in that it is likely that heavier annual dressings than those given could in many localities be advantageously used, and soil information indicates that many of the soils classed as giving no lime response will in the future require

* In the figures dealing with lime and for fertility classes (p. 139) no allowance has been made for roads, the smaller river-beds, building-sites, &c. Their extent, however, is a very small percentage of the areas quoted.

dressings. Besides the general lime position, there is worth noting also the great variations in lime requirements according to districts. In broad outline it may be said that ploughable soils located to the south of a line drawn across the Island from the Awakino River to Tauranga mainly have a small lime requirement—most come into No. 1 division and some into No. 2. North of this line to Auckland City the soils are in No. 2, with a few areas of No. 3, and in North Auckland the most abundant areas are Nos. 3 and 4.

A map showing the phosphate content and needs of our soils is being drafted, and other single-factor maps in relation to fertilizers will follow. We do not possess enough analyses to construct maps showing the quantities of trace elements in the soils, but it is obvious that with the soil types as a basis the position can be rapidly assessed from analyses of samples from the more important types. From a basis of soil types other maps than those directly dealing with fertilizers can be made—*i.e.*, according to soil texture, drainage, erosion, topography, &c. Maps showing the amount of soil loss on each of the soil types in the Gisborne and Hawke's Bay districts have already been prepared. Most important of all is a map showing the fertility or potential production of the various soils. This has already been drawn on the lines of the following legend:—

Class I .. .. Level or undulating land, not too elevated, with deep soils and favourable moisture conditions, that can be converted into high-quality farming-land.
Example: Marton, Western Taranaki, and Waikato.

Class II .. .. Ploughable land which can only be converted into fair- or medium-quality farming-land on account of some limiting factor to productivity. Group (*a*) soils in which moisture is a limiting factor. Group (*b*) soils in which some other factor such as texture, structure, drainage, elevation or depth of soil is limiting fertility.
Example: Rotorua-Taupo district, Foxton district, and most of gum land podzols soils of North Auckland.

Class III .. Ploughable land which has severe limitations to productivity and requires more investigation before development attempted.
Example: Peaty soils of Waikato and ironstone soils of North Auckland.

Class IV .. Hilly or steep land which will maintain grass pasture with little or no top-dressing. Both topsoil and subsoil are of high fertility and erosion is not a serious problem.
Example: District extending from Taihape to Turakina River, Wairarapa hill country.

Class V .. .. Hilly or steep land of moderate to low fertility. Light top-dressing is required to maintain a cover of grass and careful management necessary to prevent soil erosion.
Example: Wellington-Paraparaumu district, Waikato Heads to Raglan.

Class VI .. Hilly or steep land which has severe limitations to utilization, such as low fertility or erodibility. This class is probably more suited to forest than to grass.
Example: Tararua, Ruahine, and Raukumara ranges, Eastern Taranaki.

A preliminary estimate of the areas of the six fertility classes in the North Island is as follows:—

	Acres.	Per Cent.
Class I	3,760,000	14
Class II	2,505,000	9
Class III	1,879,000	7
Class IV	2,071,000	7
Class V	2,757,000	10
Class VI	14,740,000	53

At this point it is worth while considering what fertility means. A soil is fertile when it produces a large crop of good quality. In the classification adopted, quality has not been considered, for on this aspect there is at present very little information. Fertility needs to be considered in relation to one crop at a time. A soil may give large yields as far as pasture is concerned, but not for market-gardening, because of limitations imposed by climate, or by texture of the topsoil or subsoil, or by drainage. For the North Island fertility has been considered in relation to the growth of pasture, for this is the chief crop. On the ploughable land it has been related to a particular kind of pasture—namely, rye-grass, white clover—which gives highest production. On the hilly and steep country it is related to the ability to maintain a fairly dense pasture growth containing some clover. Obviously, if we were considering the fertility of soils in relation to market-gardening or to orcharding, the maps would have a different pattern of boundaries. In all the six classes account has been taken of not only the present fertility of the soils, but also the potential fertility when given reasonable treatment as regards fertilizers, &c. Limitations that cannot be reasonably remedied are really in the main the basis for the classification: They may be due to adverse climate, to shallowness or lightness of the soil producing droughtiness, to heavy texture making extensive drainage necessary, to the presence of a pan impeding drainage, to the presence of many logs and stumps as on peaty land, to the serious risk of soil erosion, or to the extreme poverty of the soil in plant nutrients, particularly on hilly and steep country. Taking all relevant factors into consideration, a fertility map similar in size to the soil map—4 miles to an inch—was compiled. Co-operation was obtained from the Fields Division of the Department of Agriculture and from the State Advances Corporation of New Zealand when the first draft was made.

The single-factor maps dealing with fertilizers have an immediate application. They can be used to build up a sound programme of fertilizer application, and this is of no small importance, for somewhat less than 400,000 acres (alluvial valley bottoms of recent origin) of our ploughable land is moderately well supplied with plant nutrients, and on the hilly and steep land 1,879,000 acres can get along without fertilizers. On the remaining soils that can be developed for agricultural purposes there is everywhere need for phosphate, and over a high proportion of the land for lime as well. The application of phosphate is not a simple matter, for the degree of its fixation by the soils is related broadly to the genetic group and in detail to the soil types. The fertility map gives some guidance in the selection of land during and after the war for dairying and sheep-farming. The limitations imposed by the soil and the methods necessary to raise the fertility become known. The fact that about three-quarters of the total area of hilly and steep country presents problems in its utilization shows the need for such help.

The value of the North Island soil map, however, cannot be fully realized until further surveys and researches are carried out. A survey needs now to be made to class the land according to its present use. Next a map should be constructed depicting the land uses of the soil types. The aim will be to show all the uses for which a soil can be employed, rather than aiming to decide its best use. An exception may be made in that soils best adapted for forestry may be shown. For agricultural land a soil may be classed as suited to various types of farming—*e.g.*, to dairying, fat-lamb farming, orcharding, and market-gardening—but the best use will not be selected. Such a map provides a basis for changes in land utilization demanded by changing conditions.

It also allows us to make estimates of the population that can be carried with full development under different schemes of land utilization. Further investigations based on single-factor maps, such as drainage and soil erosion, will considerably enhance their value.

In the basic scheme of land classification outlined above, the point that should be emphasized is that soil mapping must proceed well in advance of actual land classification. Soil surveying is necessarily a slow process, for boundaries have to be marked out, correlations made, and numerous chemical analyses conducted. Probably this applies to New Zealand more than to most other countries, as the soil pattern is complex owing to the diversity of topography and parent material in each district. Other surveys can proceed rapidly on this basis.

In the South Island, soil surveys have covered about half the total area. Mapping of soil types for the purposes of the basic classification outlined for the North Island has taken place almost entirely on the eastern side of the Southern Alps, the unsurveyed areas of this part embracing the lowlands from Waitaki River to Milton. Of some districts detailed maps have been published(2).

The surveys already undertaken can be regarded as coming well within the scope of the recommendation of the United Nations Conference on Food and Agriculture which recently met at Hot Springs, Virginia. For the short-term period following the war the Conference recommended "That, as a first step in overcoming the general shortage of food, every effort should be made by countries whose agriculture can be expanded in the short-term period . . . to increase the acreage under crops for direct human consumption . . . "(3). The long-term policy " of each nation should be to increase the efficiency of production through better farming methods, measures for soil conservation, the encouragement of research, and the exploitation of undeveloped areas through land clearance, drainage, and irrigation projects; and to introduce changes designed to foster the production at home of protective and relatively perishable foodstuffs "(4). Progress in New Zealand's pastoral industries, which account for more than 90 per cent. of exports, in no small measure will depend on research that aims at giving us a clearer understanding of our soil potentialities.

REFERENCES

(1) Western Taranaki: Ann. Rept., Dept. Sci. & Ind. Research, 1933.
Kerikeri: Ann. Rept., Dept. Sci. & Ind. Research, 1936.
Heretaunga Plains: Bull. 70, Dept. Sci. & Ind. Research, 1939.
Waipa County: Bull. 76, Dept. Sci. & Ind. Research, 1939.

(2) Ashburton County: Ann. Rept., Dept. Sci. & Ind. Research, 1935.
Levels Plain: Ann. Rept., Dept. Sci. & Ind. Research 1936.
Duvauchelle Bay - Wainui District, Banks Peninsula: Bull. 65, Dept. Sci. & Ind. Research, 1939.
Westport District: Bull. 71, Dept. Sci. & Ind. Research, 1939.
Wairau Plains: Bull. 72, Dept. Sci. & Ind. Research, 1939.
Balclutha and Clydevale, Tapanui and Gore Districts: Three separates, Dept. of Agri., 1943.

(3) United Nations Conference on Food and Agriculture. Govt. Printer, Wellington, New Zealand, 1943.

(4) "The United Nations Food Conference," *Nature*, Vol. *152*, No. 3844, 1943.

INVESTIGATION TO DETERMINE SUITABLE METHODS OF APPLYING COBALT SULPHATE TO PASTURES DURING FERTILIZER SHORTAGE

By P. W. MAUNSELL and J. E. V. SIMPSON, Animal Research Division, Department of Agriculture

[*Received for publication, 2nd September, 1943*]

Summary

It has been shown that, during the superphosphate shortage in New Zealand, satisfactory results can be obtained by applying cobalt to the pasture mixed with any one of the following: Superphosphate 44/46; reverted super (15 per cent. CaO); super and lime, 2 : 1; super and lime, 1 : 1; 5 cwt. lime and 1 cwt. super; lime; serpentine-super; beach sand; pumice sand; and a water solution.

INTRODUCTION

FOR some years past cobalt deficiency in New Zealand pastures has been remedied by top-dressing with cobaltized superphosphate. Owing to war conditions there is no longer enough to meet demands, and some other distributing agent had to be found. Experiments were instituted by the Department of Agriculture at the Animal Research Station, Ruakura, and at the Experimental Farm, Mamaku, to determine the most satisfactory method.

EXPERIMENTAL

Number and Size of Experimental Plots

Fourteen different cobaltized treatments were used. At Ruakura this necessitated thirty-one plots, comprising duplicates for each treatment and three controls. At Mamaku the field did not allow more than one control plot; therefore, twenty-nine in all were used. Each plot was 4 chains by ⅓ chain at Ruakura and 3 chains by ⅓ chain at Mamaku.

Materials used

All materials were analysed for cobalt content both before and after the addition of cobalt sulphate. The figures obtained are shown in Table I and II.

TABLE I.—ANALYSES OF SAMPLES BEFORE ADDITION OF COBALT

Sample.	Cobalt in p.p.m. on Dry Matter.
Beach sand	0·9
Pumice sand	0·7
Reverted super	0·5
Straight super	1·8
Lime-super	6·0
Serpentine-super	24·0
Lime	0·7

TABLE II.—ANALYSES OF SAMPLES AFTER ADDITION OF COBALT

Sample.	Cobalt in p.p.m. on Dry Matter.
1. 1 cwt. super—5 oz. cobalt sulphate	640
2. 1 cwt. reverted super (15 per cent. CaO)—5 oz. cobalt sulphate	667
3. 1 cwt. super-lime (30 per cent. $CaCO_3$)—5 oz. cobalt sulphate	667
4. 2 cwt. super and lime (1 super : 1 lime)—5 oz. cobalt sulphate	387
5. 2 cwt. super and lime—10 oz. cobalt sulphate	680
6. 5 cwt. lime and 1 cwt. super—5 oz. cobalt sulphate	113
7. 1 cwt. lime—5 oz. cobalt sulphate	673
8. 1 cwt. lime—10 oz. cobalt sulphate	1,320
9. 1 cwt. mature commercial serpentine super—5 oz. cobalt sulphate	667
10. 1 cwt. serpentine-super.—10 oz. cobalt sulphate	1,440
11. 1 cwt. beach sand—5 oz. cobalt sulphate	680
12. 1 cwt. pumice sand—5 oz. cobalt sulphate	600
13. 1 cwt. laboratory-prepared cobaltized serpentine-super—5 oz. cobalt sulphate	456

In all cases but the last the analyses gave a figure slightly higher than the theoretical and all were considered satisfactory.

The laboratory-prepared cobaltized serpentine-super had the cobalt incorporated in the acid during the preparation of the super, and the cobalt in the commercial super was mixed in afterwards. These thirteen mixtures, together with a water solution giving 5 oz. of cobalt sulphate per acre, comprised the fourteen treatments used in the experiments. Pasture samples from each plot were analysed before the top-dressings were applied.

Grazing

The experimental fields were set stocked with ewes and lambs and were grazed fairly closely, although sufficient herbage was available to enable a thoroughly clean and uncontaminated sample to be collected. The rate of growth of the pasture at Mamaku was slower than at Ruakura in the winter months (June, July, and August). The herbage was fresh and kept grazed at good "sheep feed" height throughout the duration of the experiment in both experimental areas.

Soils

The Ruakura plots were situated on peaty soil: the Mamaku plots on pumice soil from the Taupo Shower. Plots 1–14 at Mamaku were similar: but plots 15–29 were on a slope, and it was thought that some cobalt may have been washed from one plot to the next and so caused irregularities in the pasture analyses. To check this, soil samples (0–3 in. depth) were collected in November and analysed with the following results (Table III):—

TABLE III

Plot No.	Cobalt in p.p.m. sol. in HCl.	Total Cobalt in p.p.m. by HF Method.
5	1·5	2·9
7	1·0	2·4
20	1·4	2·8
24	1·5	3·0

These figures do not explain the irregularities in the October pasture samples from Mamaku.

The plots at Ruakura were top-dressed on the 2nd July, 1941, and those at Mamaku on 7th July, 1941. The first picking at Ruakura was on the 11th August, 1941, and at Mamaku on the 6th August, 1941.

Discussion

All the distributing agents in this trial gave satisfactory results. At Mamaku the lime plots and the 1 super : 1 lime plots gave the highest figures for the first few months, but were no better than the average towards the end of the trial, the reverted super, the beach sand, and the super-lime (2 : 1) plots are slightly better towards the end of the trial, but the difference is not marked enough to say these plots definitely give more lasting effects. The most remarkable results are given by the plot at Mamaku where water was the distributing medium. The figures were among the highest all through

the trial and showed a marked difference from the water plot at Ruakura, which was among the lowest all through. This may be partly due to differences in soil fixation on different soil types. The fact that the top-dressings appear to last longer at Mamaku, and the Mamaku figures are almost ten times the figures at Ruakura for the first few months, may again be due to the soil type.

TABLE IV.—RESULTS OF ANALYSES, MAMAKU FIELD 4B

Plot Nos.	Top-dressings.	Cobalt, in p.p.m. on Dry Matter.							
		June, 1941.	Aug., 1941.	Sept., 1941.	Oct., 1941.	Nov., 1941.	Dec., 1941.	Jan., 1942.	Feb., 1942.
	5 oz. of cobalt sulphate—								
1	1 cwt. serpentine-super (1 serpentine : 3 super)	0·23*	5·3	1·28	0·38	0·10	0·13	0·11	0·07
21		0·11	5·7	1·26	0·25	0·09	0·12	0·15	0·07
2	1 cwt. cobaltized serpentine-super (laboratory made)	0·12	4·4	0·92	0·26	0·10	0·13	0·10	0·07
23		0·13	3·9	1·42	0·29	0·11	0·13	0·13	0·06
3	1 cwt. pumice sand	0·15	7·0	1·28	0·36	0·10	0·13	0·12	0·07
17		0·15	6·7	1·28	0·38	0·11	0·15	0·22	0·07
4	1 cwt. reverted super	0·11	5·7	0·78	0·33	0·08	0·16	0·10	0·10
18		0·13	7·7	1·04	0·16	0·16	0·13	0·18	0·06
5	Water solution	0·12	11·6	1·72	0·64	0·09	0·14	0·11	0·04
24		0·13	9·9	2·32	0·19	0·13	0·15	0·11	0·14
8	1 cwt. super	0·09	5·5	1·26	0·25	0·10	0·14	0·09	0·06
19		0·11	5·5	1·28	0·19	0·11	0·12	0·22	0·14
9	1 cwt. lime..	0·15	9·6	1·40	0·67	0·13	0·12	0·10	0·05
22		0·09	12·1	1·48	0·15	0·12	0·11	0·09	0·07
10	1 cwt. beach sand	0·08	6·1	1·18	0·18	0·12	0·14	0·09	0·07
26		0·12	5·9	1·24	0·15	0·11	0·14	0·16	0·10
11	2 cwt. super and lime (1 super : 1 lime) ..	0·08	12·3	1·92	0·60	0·08	0·11	0·11	0·07
27		0·10	11·0	1·84	0·36	0·12	0·11	0·15	0·07
12	1 cwt. super and lime (30 per cent. $CaCO_3$) ..	0·11	10·1	1·38	0·23	0·17	0·14	0·09	0·08
16		0·13	5·9	0·84	0·13	0·12	0·17	0·11	0·07
14	5 cwt. lime and 1 cwt. super	0·12	6·8	1·54	0·15	0·11	0·13	0·09	0·06
28		0·13	6·1	1·12	0·15	0·12	0·14	0·09	0·11
	Averages	0·12	7·49	1·35	0·20	0·11	0·13	0·12	0·08
	10 oz. of cobalt sulphate—								
6	1 cwt. lime..	0·12	13·8	2·58	0·40	0·13	0·20	0·10	0·05
29		0·14	13·2	2·20	0·29	0·17	0·19	0·11	0·08
7	2 cwt. super and lime (1 super : 1 lime) ..	0·09	18·9	2·60	1·03	0·10	0·14	0·13	0·07
20		0·11	13·6	1·54	0·23	0·10	0·14	0·13	0·16
13	1 cwt. serpentine-super (1 serpentine : 3 super) ..	0·14	13·2	2·40	0·66	0·09	0·15	0·18	0·07
25		0·13	16·5	2·06	0·36	0·18	0·15	0·15	0·06
	Averages	0·12	14·8	2·23	0·50	0·13	0·16	0·13	0·09
15	Control	0·10	0·88	0·18	0·10	0·08	0·10	0·10	0·06

* Sample contaminated by soil.

At Ruakura the reverted super, lime, and 5 lime : 1 super plots were best at first, and then reverted super, super, 1 super : 1 lime, and super-lime (2 : 1) were the best.

Statistical analyses show that at Mamaku significant differences occurred between the 5 oz. top-dressed plots and the controls up to and including December; but at Ruakura no significant difference was shown after September.

A comparison of the 5 oz. cobalt sulphate top-dressings with the 10 oz. cobalt sulphate top-dressings at Mamaku shows that the latter gave a figure nearly twice as high for August, September, and October, but only

TABLE V.—RESULTS OF ANALYSES, RUAKURA FIELD 57

Plot Nos.	Top-dressings.	Cobalt, in p.p.m. on Dry Matter.						
		June, 1941.	Aug., 1941.	Sept., 1941.	Oct., 1941.	Dec., 1941.	Jan., 1942.	Feb., 1942.
	5 oz. cobalt sulphate—							
1	1 cwt. serpentine-super (1 serpentine : 3 super) ..	0·16	1·3	0·24	0·13	0·10	0·13	0·12
21		0·12	1·1	0·21	0·12	0·05	0·11	0·09
2	1 cwt. cobaltized serpentine-super (laboratory made) ..	0·16	0·8	0·18	0·13	0·10	0·14	0·12
23		0·13	0·7	0·15	0·11	0·07	0·15	0·14
3	1 cwt. pumice sand	0·15	0·7	0·20	0·15	0·08	0·14	0·12
17		0·13	0·8	0·21	0·05	0·07	0·14	0·13
4	1 cwt. reverted super	0·15	1·3	0·22	0·13	0·08	0·14	0·12
18		0·12	1·1	0·28	0·11	0·09	0·13	0·12
5	Water solution	0·14	1·4	0·15	0·12	0·07	0·11	0·10
24		0·13	1·6	0·22	0·11	0·04	0·15	0·13
8	1 cwt. super	0·13	1·0	0·20	0·13	0·09	0·16	0·14
19		0·12	0·9	0·20	0·12	0·07	0·14	0·13
9	1 cwt. lime	0·12	1·6	0·22	0·11	0·09	0·11	0·12
22		0·13	1·3	0·24	0·11	0·05	0·14	0·11
10	1 cwt. beach sand	0·12	0·8	0·20	0·13	0·08	0·10	0·11
26		0·12	0·7	0·22	0·10	0·08	0·14	0·11
11	2 cwt. super and lime (1 super : 1 lime)	0·13	1·5	0·20	0·16	0·09	0·13	0·12
27		0·12	1·4	0·21	0·15	0·08	0·11	0·16
12	1 cwt. super and lime (30 per cent. $CaCO_3$)	0·13	1·2	0·22	0·18	0·09	0·13	0·11
16		0·12	1·6	0·22	0·13	0·07	0·11	0·09
14	5 cwt. lime and 1 cwt. super	0·14	1·7	0·23	0·15	0·07	0·14	0·09
28		0·19*	1·3	0·23	0·09	0·05	0·10	0·13
	Averages	0·13	1·16	0·21	0·13	0·08	0·13	0·12
	10 oz. cobalt sulphate—							
6	1 cwt. lime	0·13	1·9	0·37	0·16	0·08	0·13	0·11
29		0·15	2·0	0·48	0·17	0·11	0·11	0·14
7	2 cwt. super and lime (1 super : 1 lime)	0·12	2·9	0·29	0·17	0·08	0·13	0·12
20		0·12	1·5	0·26	0·15	0·10	0·13	0·09
13	1 cwt. serpentine-super (1 serpentine : 3 super) ..	0·14	2·2	0·26	0·16	0·07	0·15	0·12
25		0·15	1·7	0·26	0·16	0·11	0·15	0·14
	Averages	0·13	2·0	0·32	0·17	0·09	0·13	0·12
C1 ..	Control	..	0·36*	0·13*	0·09	0·08	0·10	0·12
15 ..	,, ...	0·14	0·17	0·09	0·18*	0·06	0·10	0·08
C2 ..	,, ...	..	0·11	0·09	0·09	0·06	0·10	0·10
	Averages	0·14	0·11	0·09	0·09	0·07	0·10	0·10

* Sample contaminated by soil.

slightly higher from November onward. At Ruakura there was very little difference between the two from September onwards.

This confirms the results of other experiments, which indicate that annual top-dressing with more than 5 oz. cobalt sulphate is not justified in practice.

A CASE OF COMBINED POTASSIUM AND BORON DEFICIENCIES IN GRAPES

By H. O. ASKEW, Cawthron Institute, Nelson, New Zealand

[*Received for publication, 18th November, 1943*]

Summary

A chlorosis, and later collapse, of the leaves of vines at Braeburn, Nelson, has been found to be due to a deficiency of potash. Applications of sulphate of potash caused the disappearance of the symptoms and brought about vigorous, healthy growth.

A disorder of the flesh of the berries was controlled by the use of borax in the fertilizer applications.

Data for potash and boron contents of leaves and berries from the experimental area are shown to correlate with the field observations.

INTRODUCTION

IN the summer of 1941 the unsatisfactory condition of the leaves and berries of an area of grapes (variety Albany Surprise) at Braeburn, in the Nelson District, was brought to the attention of the Cawthron Institute. The symptoms suggested that possibly both potash and boron deficiencies were connected with the unsatisfactory appearance of the vines and berries.

EXPERIMENTAL

The vines were growing on a poor phase of the Moutere clay-loam type of soil, a type widespread in the Nelson District, which is not only very deficient in lime and phosphate, but in some locations has been found to be deficient also in boron and magnesium. In the neighbourhood of these grape-vines apples show internal cork - a boron-deficiency disease. At the time the above report of their condition was received the vines were about four years old and had been fertilized only with blood-and-bone mixture or with superphosphate. Until the 1940–41 season the vines had apparently been healthy, at least nothing was noticed to seriously alarm the owner, but in this season the leaves of the vines were in very poor condition and a large portion of the berries could not be harvested owing to internal damage to the flesh.

DESCRIPTION OF SYMPTOMS

When first inspected the leaves had a strongly-developed chlorosis between the main veins together with a scorched and ragged edge. The setting of the fruit had been very irregular, and brown areas of tissue appeared in the flesh of some of the berries.

Further details of the symptoms as noted in succeeding seasons were as follows :—

Leaves.—The first symptoms were a light chlorotic mottling between the main veins. These chlorotic areas changed to a reddish-brown and later to a purplish-brown colour. By the time these latter symptoms had appeared the edges of the leaves had become scorched and curled upwards and inwards. Affected leaves were very ragged. In Fig. 1 are shown leaves from the area under discussion ; the one on the left is from a healthy vine, and the one on the right from an unhealthy vine.

Berries.—Vines which received no potash and/or no borax in the fertilizer set poor bunches of fruit which later carried a number of withered berries as shown in Fig. 2, where the bunch on the left is from a fully-fertilized plot and that on the right from a plot receiving neither potash nor borax. While absence of potash caused poor fruiting, it did not lead to any development of dead tissue within the fruit. This was apparently due to lack of boron. The early stages of this disorder were shown by brownish-green areas showing under the skin of even quite young and immature berries. These areas developed in size later, and from Fig. 3 it can be seen that extensive areas of some berries were affected. In this photograph the top row shows the external appearance of some affected berries, while the lower row shows the same berries after thin slices of flesh had been removed to exhibit the death of the tissue.

FIG. 1.—Grape leaves (variety Albany Surprise) showing healthy leaf on left and potash-deficient leaf on right.

EXPERIMENTAL

By courtesy of the owner four rows of vines were made available for fertilizer trials. A unit of six vines, consisting of three vines in each of two rows, was taken. Two replications of each treatment were provided. The area was gently sloping, the higher end having the poorest soil. In plan, the plots were arranged as follows. (Only the K and B treatments are shown, as nitrogen and phosphate were supplied to all plots.) The vines had been planted 12 ft. apart in the rows, with the rows 8 ft. apart, this giving about 360 vines per acre.

Slope ↓	Plot 1: K and B.	Plot 2: B.	Plot 3: K.	Plot 4: Nil.	Plot 5: K and B.
	Plot 6: K.	Plot 7: Nil.	Plot 8: K and B.	Plot 9: B.	Plot 10: K and B.

Slope——————>

NOTE.—All plots received nitrogen and phosphate. Plots 1, 2, 6, and 7 are on poor soil. Plots 4, 5, 9, and 10 are on deeper soil. Plots 3 and 8 are on intermediate soil.

FIG. 2.—Healthy grapes on left and poor bunch on right.

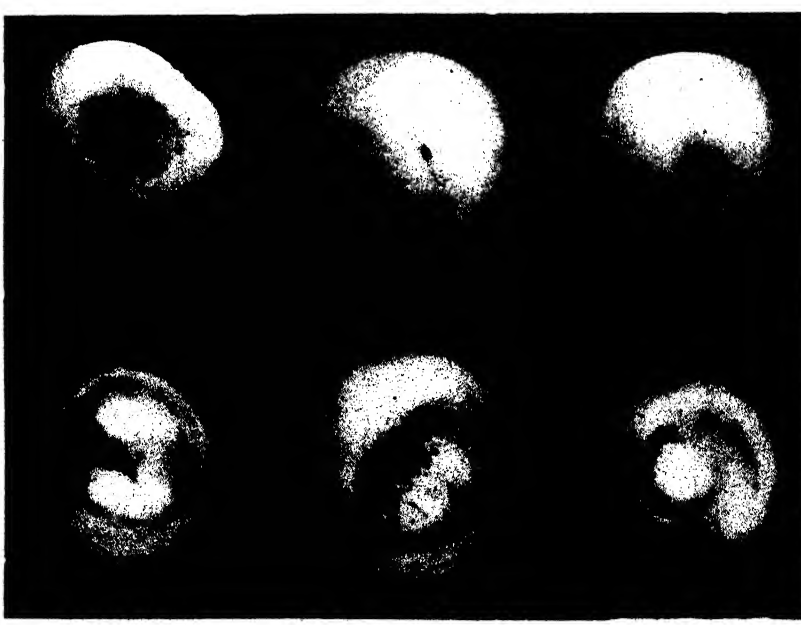


FIG. 3.—Berries affected with internal browning. Top row, external view; bottom row, same berries out to expose damaged tissue.

Nitrogen was supplied in the forms of sulphate of ammonia ($1\frac{1}{2}$ cwt. per acre) and dried blood ($1\frac{1}{2}$ cwt. per acre). Potash was given as sulphate of potash (4 cwt. per acre), and phosphate as superphosphate (6 cwt. per acre). The fertilizer, after mixing, was applied in a band about 3 ft. wide on each side of the rows of vines to 3 ft. beyond the last vine of each plot, which provided a space of 6 ft. of unmanured soil between each plot.

Borax at the rate of 28 lb. per acre was spread in a circular band about 1 ft. wide, but not approaching within 1 ft. of the stem of the vine. Some was also sprinkled along the rows between the vines. The fertilizers were finally cultivated into the soil. In the two seasons of the experiment the fertilizer applications were made on 29th July, 1941, and on 23rd July, 1942.

In the 1941–42 season the potash application exerted a very beneficial effect in reducing the amount of chlorosis and subsequent scorching. Where no potash had been used, distinct evidence of chlorosis was visible in mid-January. By mid-February there were many reddish-brown affected areas on the leaves. Potash-treated vines were generally healthy in appearance. By mid-March the non-potash vines were in a very poor condition with discoloured and ragged leaves. At the end of the season the no-potash plots did not show nearly as much new growth as the potash-treated ones. Soil conditions improve on these plots in passing towards plots 5 and 10; consequently the vines were healthier and the effects of the potash applications were not very noticeable on these plots. No effect on the vegetative growth was noticed as the result of using borax.

Browning in the flesh of the berries was present where no borax had been used, being especially severe on plots 6 and 7. No actual counts of the incidence were made, only visual estimates of degree being noted. On badly-affected bunches probably 50 per cent. of the berries were affected.

In the 1942–43 season the treatments were repeated. Potash-treated vines did very well, coming away earlier in the spring and carrying throughout the season a heavy growth of large, healthy leaves; no sign of chlorosis was seen on these vines. On no-potash vines chlorosis had appeared on mature leaves by the beginning of November. A number of small brown spots also appeared on the leaves, which appeared to be an early stage of breakdown of the leaf blade. This spotting had been noted in a mild form in the previous season, but fairly late in the season. No fungal infection could be demonstrated in these spots. By the beginning of December these symptoms were very marked, especially on the poorer soil. By mid-February the vines on the poorer soil without potash treatment (plots 2 and 7) were in a very poor condition with very marked chlorosis and scorching of the leaves and poor top growth. On the better soil a slight amount of chlorosis was seen on the no-potash plots. All potash-treated plots had a strong, vigorous growth with a heavy crop of fruit. The berries ripened more regularly on the plots with complete treatment; in the absence of potash, ripening was irregular. In early January the first browning of the flesh of the berries was seen on plot 7. By mid-February there was a considerable amount of affected fruit on plots 6 and 7, which did not receive borax. On plots 3 and 4, also without borax but on better soil, there was only a small amount of affected fruit. The impression was gained that, in general, the disorder in the fruits was not so severe as in the previous season.

During the two seasons of these experiments the postash-treated vines have improved steadily in condition, and by the end of the 1943 season they appeared to be perfectly healthy. The borax treatment has effectually

controlled the flesh disorder. The owner of the area has used the same fertilizer mixture, with the exception that only 14 lb. of borax per acre was used instead of the 28 lb. used experimentally, with very satisfactory results both in growth of the vines and in yield of fruit.

CHEMICAL ANALYSIS OF LEAVES AND BERRIES

In both seasons samples of leaves and berries were taken for chemical analysis. A full set covering all plots was taken in the 1941–42 season, but in 1942–43 only plots 1, 2, 6, and 7 were sampled. It will be noted that these last plots cover the four treatments with and without potash and borax and were those on which the most striking benefit was obtained from the fertilizer applications.

For leaf samples the blades only were collected. For fruit samples the berries were stripped from the bunches and dried whole.

The samples were carefully ashed to obviate loss of potash, and after taking up the ash in dilute hydrochloric acid the potash was estimated by the perchlorate method. Boron was determined on a separate lot of ashed material by the quinalizarin method. Results for the two seasons' samples are given in Table I:

TABLE I.—PARTIAL CHEMICAL ANALYSIS OF SAMPLES OF GRAPE LEAVES AND BERRIES, EXPRESSED ON THE DRY BASIS

Plot No.	1.	2.	6.	7.	3.	8.	4.	5.	9.	10.
Treatment	K & B.	B.	K.	Nil.	K.	K & B.	Nil.	K & B.	B.	K & B.
Leaves										
1941–42—										
Ash, per cent.	4·97	4·61	4·45	4·41	5·11	5·96	6·62	7·47	7·48	6·72
Potash (K_2O), per cent. ..	0·66	0·38	0·54	0·32	0·66	0·61	0·67	0·68	0·71	0·59
Boron (B), p.p.m.* ..	39·2	41·8	5·5	10·3	11·0	40·5	12·4	32·4	33·6	33·0
1942–43—										
Ash, per cent.	6·61	5·88	6·37	5·00	..	..	..	..	..	..
Potash (K_2O), per cent. ..	0·93	0·53	0·83	0·49	..	..	..	..	..	..
Boron (B), p.p.m.* ..	29·1	33·9	14·6	19·1	..	..	..	..	..	..
Berries										
1941–42—										
Ash, per cent.	2·89	2·11	2·59	2·14	2·61	3·48	3·17	4·10	4·46	3·40
Potash (K_2O), per cent. ..	0·92	0·64	0·83	0·65	0·90	1·04	1·06	1·23	1·31	1·17
Boron (B), p.p.m.* ..	26·6	15·0	4·6	4·4	7·2	29·2	7·5	30·0	31·2	29·0
1942–43—										
Ash, per cent.	4·90	2·44	3·39	2·45	..	..	..	..	..	..
Potash (K_2O), per cent. ..	1·30	0·71	1·14	0·72	..	..	..	..	..	..
Boron, (B) p.p.m.* ..	33·9	21·6	6·4	8·8	..	..	..	..	..	..

* P.p.m. = parts per million.

NOTE.—K supplied as sulphate of potash and B as borax. All plots received uniform N and P treatment.

It is evident from these analytical data that, especially on the poorer soil (plots 1, 2, 6, and 7), in each season the applications of sulphate of potash have markedly increased the potash contents of the leaves and berries. Plots 4, 5, and 10, on the better soil, show little difference due to the potash applications. Plots 3 and 8 are comparable in soil conditions, being intermediate between the groups mentioned above. It will be noted, too, that the potash contents are in harmony with the presence or absence of leaf symptoms; the two plots showing much the worst symptoms have only about half the amount of potash found in the healthy leaves.

Wherever borax has been applied the boron contents of both leaves and fruit have been greatly increased. Thus on the no-borax plots the average boron content of the leaves was 9·8 p.p.m., whereas that of the borax-treated plots was 36·7 p.p.m. in the 1941–42 season. In the berries the corresponding figures for no-borax and borax-treated areas were 5·9 p.p.m. and 26·8 p.p.m. Low boron content of the berries is correlated with the appearance of severe browning of the flesh of the berries, while high boron content is associated with healthy fruit.

DISCUSSION

The potash content of the blades of the leaves of vines in this experiment is of the same order as that found by Ulrich(1) for vines growing on soil which gave responses to potash fertilization. Ulrich's vines were, however, apparently not exhibiting any symptoms in the leaves, as he makes no reference to such an occurrence. In the present case the increase in potash content following fertilization was more marked than in Ulrich's experiment. A variation in potash content from season to season is seen in the present results as in that of the American investigator. The continuing development of leaf symptoms on vines not receiving potash and the non-development of symptoms after the use of potash in the fertilizer, combined with the correlation of intensity of symptoms with potash content of the leaves, definitely indicates that the leaf symptoms in the Nelson vines were due to a deficiency of potash.

The potash status of the vines exerted a definite effect on the yield of fruit by influencing the development and uniformity of ripening of the berries. Low boron status showed a detrimental effect on yield by the shrivelling and disfigurement of the berries due to internal collapse of the tissues. The non-development of the browning of the tissues of the berries where borax was used, combined with the correlation between boron content and health of berries, suggests that this disorder was due to lack of boron.

Leaf symptoms which might be correlated with the boron status of the vines were not seen, certainly nothing of the type reported by Scott(2). The lowest figure (5·5 p.p.m.) found in the present trial is of the same order as that found by Scott (6 p.p.m.) for leaves from badly-affected vines, although one variety developed "extreme symptoms" when showing 24 p.p.m. of boron(2). The use of 10 lb. of borax per acre on the American vines raised the boron contents of the leaves to from 19 p.p.m. to 54 p.p.m. In the Nelson vines 28 lb. of borax gave a maximum figure of 42 p.p.m. What may be regarded as normal values for the boron content of grape leaves appear to be lacking in the literature. Magoon *et al.*(3) found for young leaves of Concord and Ontario vines receiving a complete fertilizer average values of 17 p.p.m. and 16 p.p.m. respectively.

For the boron content of grape berries recent data appear to be lacking, and no reference has been found to the type of internal disorder found on the Nelson vines. Older values for boron content range from 7 p.p.m. to 39 p.p.m. but it is not clear from the abstracts of the original papers whether these are expressed on the fresh or the dry basis. The highest of these figures corresponds to that from the borax-treated vines in the present experiment.

There appears to be a definite seasonal influence on the boron content of both the leaves and fruit, to be seen especially on those plots where the boron supply was low. In the 1942–43 season the boron contents of such plots were appreciably higher than in 1941–42. The lower incidence of damage to the fruit in the 1942–43 season may be correlated with the better boron status in this season.

ACKNOWLEDGMENTS

Grateful acknowledgment is made of the co-operation of Mr. F. W. Tillson, of Braeburn, Nelson, in allowing the use of some of his vines for the purposes of this experiment; to Dr. K. M. Curtis for examining leaves for the possible presence of fungal infection; and to Mr. D. G. Annear for field assistance and for preparing the samples for analysis. Mr. W. C. Davies kindly prepared the illustrations.

REFERENCES

(1) ULRICH, A. (1942): *Proc. Am. Soc. Hort. Sci.*, *41*, 204.
(2) SCOTT, L. E. (1941): *Proc. Am. Soc. Hort. Sci.*, *38*, 375.
(3) MAGOON, C. E., *et al.* (1939): *Proc. Am. Soc. Hort. Sci.*, *36*, 485.

RESEARCH ON *ANOBIUM PUNCTATUM* DE GEER

THE FLIGHT PERIOD AT AUCKLAND

By WINSOME DENNE, Assistant Mycologist, D. SPILLER, Entomologist, Plant Diseases Division, and J. M. KELSEY, Assistant Entomologist, Entomology Division, Department of Scientific and Industrial Research

[*Received for publication, 19th May, 1944*]

INTRODUCTION

THE house borer or common furniture beetle *Anobium punctatum* de Geer is a widespread pest of sapwood timber in buildings and furniture throughout New Zealand. In 1940 a research programme was initiated on the suitability of the beetle as a test insect for the evaluation of timber therapeutants, and for this it has been necessary to collect a very large number of beetles from various sources in Auckland—viz., infested buildings and discarded timber. As records have been kept of the emergence of the adults there has accumulated a body of information on the flight period of the insect in this area, and such information is presented in this paper.

Thomson (1922) has recorded the opinions of several observers concerning the flight period of *A. punctatum* in the Dominion. The extreme range was from October to January, with the maximum regarded as occurring during the middle of December. One observer stated that the beetle emerged only during the second and third weeks of December. Miller (1925) has stated that the adults emerge during the months of October, November, and December. Smith and Forbes (1944) gave the flight period in Wellington as extending from December to March, but earlier in the North and later in the South.

TECHNIQUE AND RESULTS

The records have been made over the last three years and are based on the flight of over fifteen thousand beetles collected from the sources shown below. The timber for (1), (2), and (3) below was collected from varying locations within the city, and in each case the timber was sorted and most of

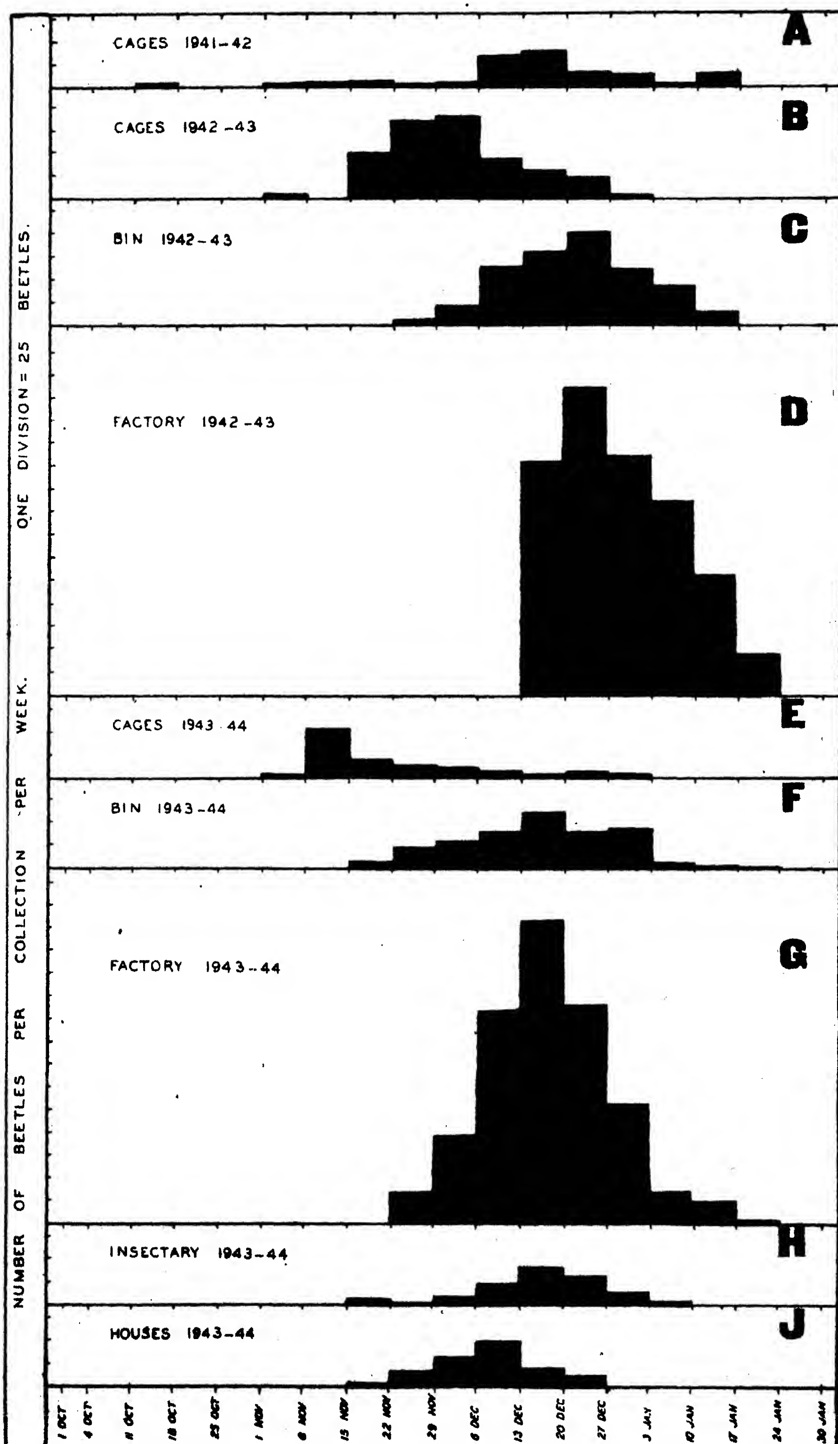

A
CAGES 1941–42
B
CAGES 1942–43
C
BIN 1942–43
D
FACTORY 1942–43
E
CAGES 1943–44
F
BIN 1943–44
G
FACTORY 1943–44
H
INSECTARY 1943–44
J
HOUSES 1943–44
NUMBER OF BEETLES PER COLLECTION PER WEEK. ONE DIVISION = 25 BEETLES.
1 OCT
4 OCT
11 OCT
18 OCT
25 OCT
1 NOV
8 NOV
15 NOV
22 NOV
29 NOV
6 DEC
13 DEC
20 DEC
27 DEC
3 JAN
10 JAN
17 JAN
24 JAN
30 JAN

FIG. 1

it renewed each year. The records of (4) and (5) were obtained by collecting *in situ* from the surfaces of the infested timbers :—

(1) Six *cages* housing approximately 500 superficial feet of timber kept in the basement of the laboratory. Results for the seasons 1941–42, 1942–43, and 1943–44 are shown in Fig. 1 : A, B, and E.

(2) A large *bin* housed in a well-ventilated shed and holding approximately 1,000 superficial feet of timber. Results for the seasons 1942–43 and 1943–44 are shown in Fig. 1 ; C and F.

(3) In 1943–44, approximately 700 superficial feet of offcuts and surplus timber housed in an *insectary*. See Fig. 1 : H.

(4) A large and heavily infested city *factory* which became available for collection purposes in December, 1942, and was again available in the season 1943–44. See Fig. 1 : D and G.

(5) During the season 1943–44 two *houses* at Mount Roskill. See Fig. 1 : J.

In the main, collections were made daily, except at the week-ends and over Christmas and the New Year.

Since the numbers collected from each source showed considerable variation from day to day, the results were smoothed by grouping, and the frequency histograms were calculated as the average number of beetles per collection in each week. Results are shown thus in Fig. 1.

DISCUSSION

The results show that no beetles have been collected before the middle of October or after January. The main emergence, however, covered five weeks from the beginning of December, and although there was some variation in the maximum flight period, with two exceptions—viz., Fig. 1 ; B and E—all occurred in the second, third, or fourth weeks of that month. Fig. 1 : B and E are of value in indicating that at times the maximum flight may occur outside this range.

REFERENCES

MILLER, D. (1925) : Forest and Timber Insects in New Zealand. *N.Z. State Forest Service Bull. No. 2*, p. 50.

SMITH, J. H., and FORBES, A.-C. (1944) : How to defeat Wood Borers. *N.Z. J. Agr.*, *68* (*2*), pp. 83–88.

THOMSON, G. M. (1922) : "The Naturalisation of Animals and Plants in New Zealand," p. 293. Cambridge University Press.

IMPERIAL AGRICULTURAL BUREAUX

RECENT AND FORTHCOMING PUBLICATIONS ON AGRICULTURE AND FORESTRY

THE following publications by the Imperial Agricultural Bureaux are now available from the Central Sales Branch, Agricultural Research Buildings, Penglais, Aberstwyth, Wales. All publications are postage free, except where otherwise stated.

ADMINISTRATIVE

IMPERIAL AGRICULTURAL BUREAUX

"Report of a Committee presided over by the Rt. Hon. Lord Hankey, G.C.B., G.C.M.G., G.C.V.O., F.R.S." Price, 1s.

"Reports on the Parasite Service." 1940–41 to 1942–43. Price, 1s.

JOINT PUBLICATIONS

JOINT PUBLICATION NO. 6

"Alternate Husbandry." Price, 5s.

JOINT PUBLICATION NO. 7

"*Imperata cylindrica*: Its Economic Significance and Control." Price, 2s. 6d.

IMPERIAL MYCOLOGICAL INSTITUTE

MYCOLOGICAL PAPER NO. 6

"Colour Terminology in Biology," by H. A. Dade. Price, 3s. 9d.

MYCOLOGICAL PAPER NO. 7

"Notes on Indian Fungi—I," by G. Watts Padwick and J. L. Merh. Price, 1s. 6d.

MYCOLOGICAL PAPER NO. 8

"A Preliminary List of Plant Diseases in Jamaica," by N. H. Larter and E. B. Martyn. Price, 2s. 3d.

"A DICTIONARY OF THE FUNGI"

"A Dictionary of the Fungi" by G. C. Ainsworth and G. R. Bisby. Price, 20s., or U.S. $4·60.

IMPERIAL BUREAU OF SOIL SCIENCE

TECHNICAL COMMUNICATION NO. 41

"The Take-all Disease of Cereals," by S. D. Garrett. Price, 2s. 6d.

TECHNICAL COMMUNICATION NO. 42

"The Mineralogy of Soil Colloids," by G. Nagelschmidt. Price, 2s. 6d.

IMPERIAL BUREAU OF ANIMAL HEALTH

"Antibacterial Agents derived from Micro-Organisms," by Ruth Allcroft. Price, 1s.

"The Present Position of Phenothiazine as an Anthelmintic," by D. G. Davey and J. R. M. Innes. Price, 1s. 6d.

IMPERIAL BUREAU OF PLANT BREEDING AND GENETICS

"Bibliography on Insect Pest Resistance in Agricultural Plants" (with a Supplement on Resistance to Nematodes). Price, 1s. 6d.

"New and Promising Varieties recently described in the Literature." April, 1942—Fourth List: price, 1s. October, 1943—Fifth List; price, 1s.

"Potato Collecting Expeditions in Mexico and South America—II. Taxonomy and Systematic Classification of the Collections," by J. G. Hawkes. Price, 7s. 6d.

IMPERIAL BUREAU OF ANIMAL BREEDING AND GENETICS

"Gestation Periods: A Table and Bibliography," by J. H. Kenneth Price, 2s.

IMPERIAL BUREAU OF HORTICULTURE AND PLANTATION CROPS

"Index to Horticultural Abstracts," Volumes I–X, 1931–1940. Compiled by D. Akenhead. Price, 25s.

TECHNICAL COMMUNICATION NO. 14

"Propagation by Cuttings and Layers," by R. J. Garner. Recent work and its application with special reference to pome and stone fruits. Price, 3s. 6d.

IMPERIAL BUREAU OF AGRICULTURAL PARASITOLOGY (HELMINTHOLOGY)

"Bibliography of Phenothiazine as an Anthelmintic." Price, 2s. (Issued free to subscribers to Helminthological Abstracts, Vol. XI.)

IMPERIAL FORESTRY BUREAU

TECHNICAL COMMUNICATION NO. 1

"Gas-producers for Motor-vehicles and their Operation with Forest Fuels." by I. Kissin. Price, 3s.

TECHNICAL COMMUNICATION NO. 2

"Co-operation in Forestry," by I. Kissin. Price, 4s.

REPRINTS FROM FORESTRY ABSTRACTS

"Wood-waste Utilization," by W. G. Campbell and P. Harris. (From Forestry Abstracts, Vol. 4, No. 2, 1942.) 5 pp. Price, 1s.

"Forests and Forestry in Norway," by Finn Frost. (From Forestry Abstracts, Vol. 4, No. 3, 1943.) 4 pp. Price, 1s.

"The Land-use Movement in West Africa," by J. N. Oliphant. (From Forestry Abstracts, Vol. 4, No. 4, 1943.) 6 pp. Price, 1s.

THE NEW ZEALAND

JOURNAL OF SCIENCE AND TECHNOLOGY

Editor: D. Cairns, M.Sc., Department of Scientific and Industrial Research, Wellington

VOL. 26, SEC. A | DECEMBER, 1944 | NUMBER 4

NEW ZEALAND BACON PIG JUDGING STANDARDS

By C. P. McMEEKAN*, H. M. PEIRSON†, H. E. JOHNSON‡, H. KNEEBONE§, F. MERRIT||, and J. D. ANDERSON¶

[Received for publication, 29th September, 1944]

Summary

This report presents the details of a system of evaluating the New Zealand bacon pig carcass. The method suggested has been evolved by a technical committee set up by the New Zealand Department of Agriculture.

The system is based upon the use of linear carcass measurements and upon eye-judgment of characters not readily measurable by objective means. Of a total of 100 points, 60 are awarded on direct measurements and 40 on eye-judgments. To reduce to a minimum errors due to the personal factor in eye-judgments photographic standards for such characters are presented.

The system is designed to cover pigs which fall within the optimum bacon weight of 130 lb. to 160 lb. dressed carcass weight.

Use of the system in competitions involving over four thousand pigs has demonstrated its capacity to sort out the type of carcass required by the bacon trade.

The system has been adopted as the official standard judging system for bacon pigs by the National Pig Industry Council and the New Zealand Pig Breeders' Association.

DURING the past ten years enthusiasts interested in the improvement of the New Zealand bacon pig have developed various systems of judging baconers. Commencing with a simple method of eye-judgment, in which bacon-curers and others associated with the trade merely selected the best-looking carcasses as prize winners, more and more reliance upon direct measurements of particular characters has gradually replaced guesswork. Such direct measurements were a decided advantage over eye-judgments in that they eliminated the personal factor and, in addition, provided definite standards at which the breeder of pigs could aim and by which he could measure his progress from year to year.

* McMeekan, C. P., Superintendent, Ruakura Animal Research Station, Department of Agriculture.

† Peirson, H. M., Superintendent, Pig Industry, Department of Agriculture.

‡ Johnson, H. E., Representing Pig Breeders' Association.

§ Kneebone, H., Supervising Grader for Auckland Farmers' Freezing Co.

|| Merrit, F., Supervising Grader, Meat Board, Auckland.

¶ Anderson, J. D., Supervising Grader, W. R. Fletcher, Westfield, Auckland.

This application of direct measurements to the evaluation of a bacon-pig carcass culminated in the development of the so-called "Smithfield System" of judging, provided by the well-known British authorities, Messrs. J. B. S. Swain, of Empire Port House; H. R. Davidson, of Harpendon, Hert.; Dr. John Hammond, of Cambridge University; and Mr. N. L. Wright, of the New Zealand Department of Scientific and Industrial Research, London(1). This system was evolved over a period of years in direct response to requests from New Zealand producers for standards which would enable them to assess accurately the suitability of their pigs for British trade requirements. The Smithfield system depended almost entirely on careful measurements of back-fat, length, leg-length, and muscle-development. It involved cutting the carcass in the loin region to enable its internal composition to be measured. The system set a high standard of excellence, the average New Zealand pig scoring only about 50 per cent. of the possible marks. Due partly to this severity in judgment, but more to the fact that cutting of the carcass involved a financial loss which it has not been possible for interested organizations to meet on every occasion, the system has been used only to a limited degree. Only in one or two areas where suitable arrangements for cutting have been possible has it been in continuous use. In other districts judges have been forced to improvise modifications of a type involving no serious disturbance to normal trade practices. In these, cutting of the carcass has been dropped and measurement of eye-muscle, and fat over the eye, eliminated. More reliance has had to be placed on eye-judgment.

As one such modification, the National Pig Industry Council has used a system designed to bring judging results into line with commercial grading of bacon pigs. Measurements that could be obtained readily were retained, but even here standards asked for were suitably lowered in comparison with the Smithfield scale. This system raised the average mark of competition pigs to somewhere near the 80 per cent. level, and thus gave a good comparison with commercial grading under which about 80 per cent. of pigs grade No. 1 Prime. While achieving this objective it was soon found subject to the very severe criticism that it did not give sufficient scope in judging to allow full credit to the really superior carcass or sufficient penalty to the really inferior pig.

Difficulties of this type soon focused attention on the point that it is not practicable to employ the same methods both for judging pigs in competition work and for commercial grading. In commercial grading a system is needed that will sort out three or four reasonably uniform lines of commercial carcasses. In such lines there can, and will, be a good deal of variation in type, but, on the average, the carcasses of any particular grade will be suitable for the purposes intended. On the other hand, in judging pigs as individuals a system is needed that will sort out carcasses in order of individual merit. To do this it is essential that a wide range of marks be both available and used. For example, in the National Council method as used in recent competitions full marks for back-fat were awarded to any pig that graded No. 1 Prime. Since a large tolerance in back-fat measurements is allowed under the commercial grading system this meant that pigs with ideal fat received the same mark as others that were much fatter or leaner. No separation of pigs in order of merit was possible. This naturally led to considerable confusion on the part of exhibitors and farmers viewing the prize-winning entries. Since all of these systems have been used in different districts of recent years it is obvious that there has been no uniformity in judging. To secure such uniformity the Department of Agriculture recently set up a technical committee composed of the writers of this report. Having

wide practical experience in trade requirements and carcass evaluation work, and representing all interested parties, it was hoped that this committee could evolve a system which would be accepted throughout New Zealand.

In approaching the problem the committee had in mind the following essential requirements:—

(1) That measurements should be employed wherever practicable:

(2) That, where eye-judgment is unavoidable, photographic standards should be used as a guide to judges:

(3) That the system should be so balanced that no one character should outweigh another, but rather that an all-over good type animal should be sorted out:

(4) That, to be workable, the method should not conflict with established trade practices of processing and marketing.

In evolving the system hereafter described the committee has taken advantage of the data available from many carcass competitions of past years, and has tried out tentative methods in recent competitions involving over four thousand pigs. It is satisfied that, in the hands of experienced judges, the system provides an accurate measure of the excellence of a bacon carcass, and will sort out the type of carcass required by the Wiltshire bacon trade both in New Zealand and overseas.

METHOD OF POINTING

A maximum of 100 points are allotted each pig. These are based upon 60 points obtained from direct measurements and 40 points obtained from eye-judgment. The distribution of the points is as follows:—

	Maximum Points.
Direct Measurement—	
Length	20
Shoulder-fat	10
Loin-fat	20
Balance and depth	10
Eye-judgment—	
Hams	15
Fore end (shoulders)	10
Fullness of meat	10
Marketing points	5
Total	100

Disqualifications.—In view of the impossibility of making fair allowance for disease and other important defects, the following characters automatically disqualify an entry from being placed in any competition, but will not necessarily prevent such an entry being evaluated under the system: *extensive seedy cut; excessively soft or discoloured fat; pigs rejected or condemned in part or whole by normal grading practice.*

It will be observed that headless pigs and pigs rejected for export on account of pleurisy are thus disqualified.

WEIGHT RANGE

The system applies with accuracy only to pigs of optimum bacon weight—to pigs from 130 lb. to 160 lb. dressed weight. It is strongly recommended that competitions be limited to pigs within this weight range. To enable pigs outside this range to be evaluated where necessary, the following tables

include measurements for lighter and heavier weights. It must be stressed, however, that pigs lighter than 130 lb. will score better than they should. Heavy-weight pigs, since these are undesirable under normal conditions, will tend to be penalized. Within the true bacon-weight range the system gives an even chance to a pig to score well, irrespective of its weight.

LENGTH. (20 Points)

Length is measured to the nearest $\frac{1}{4}$ in. in a direct line from the aitch-bone (symphysis-pubis) to the junction between the first rib and the sternum (see Fig. 1). The standard required is comparable with that of the Smithfield system and, as a general guide, a length of $32\frac{1}{4}$ in. for a pig of 141 lb. to 145 lb. is demanded for maximum points. For each $\frac{1}{4}$ in. below this standard, 1 point is deducted. Actual points for length in relation to weight are shown in Table 1.

TABLE 1.—SCALE OF POINTS FOR LENGTH

(Length in inches and quarter inches)

Points.	Light Weight.		Carcass Weight (Lb.).						Heavy Weight.	
	121–125.	126–130.	131–135.	136–140.	141–145.	146–150.	151–155.	156–160.	161–165.	166–170.
1	26^{2}	26^{3}	27^{0}	27^{1}	27^{2}	27^{3}	28^{0}	28^{1}	28^{2}	28^{3}
2	26^{3}	27^{0}	27^{1}	27^{2}	27^{3}	28^{0}	28^{1}	28^{2}	28^{3}	29^{0}
3	27^{0}	27^{1}	27^{2}	27^{3}	28^{0}	28^{1}	28^{2}	28^{3}	29^{0}	29^{1}
4	27^{1}	27^{2}	27^{3}	28^{0}	28^{1}	28^{2}	28^{3}	29^{0}	29^{1}	29^{2}
5	27^{2}	27^{3}	28^{0}	28^{1}	28^{2}	28^{3}	29^{0}	29^{1}	29^{2}	29^{3}
6	27^{3}	28^{0}	28^{1}	28^{2}	28^{3}	29^{0}	29^{1}	29^{2}	29^{3}	30^{0}
7	28^{0}	28^{1}	28^{2}	28^{3}	29^{0}	29^{1}	29^{2}	29^{3}	30^{0}	30^{1}
8	28^{1}	28^{2}	28^{3}	29^{0}	29^{1}	29^{2}	29^{3}	30^{0}	30^{1}	30^{2}
9	28^{2}	28^{3}	29^{0}	29^{1}	29^{2}	29^{3}	30^{0}	30^{1}	30^{2}	30^{3}
10	28^{3}	29^{0}	29^{1}	29^{2}	29^{3}	30^{0}	30^{1}	30^{2}	30^{3}	31^{0}
11	29^{0}	29^{1}	29^{2}	29^{3}	30^{0}	30^{1}	30^{2}	30^{3}	31^{0}	31^{1}
12	29^{1}	29^{2}	29^{3}	30^{0}	30^{1}	30^{2}	30^{3}	31^{0}	31^{1}	31^{2}
13	29^{2}	29^{3}	30^{0}	30^{1}	30^{2}	30^{3}	31^{0}	31^{1}	31^{2}	31^{3}
14	29^{3}	30^{0}	30^{1}	30^{2}	30^{3}	31^{0}	31^{1}	31^{2}	31^{3}	32^{0}
15	30^{0}	30^{1}	30^{2}	30^{3}	31^{0}	31^{1}	31^{2}	31^{3}	32^{0}	32^{1}
16	30^{1}	30^{2}	30^{3}	31^{0}	31^{1}	31^{2}	31^{3}	32^{0}	32^{1}	32^{2}
17	30^{2}	30^{3}	31^{0}	31^{1}	31^{2}	31^{3}	32^{0}	32^{1}	32^{2}	32^{3}
18	30^{3}	31^{0}	31^{1}	31^{2}	31^{3}	32^{0}	32^{1}	32^{2}	32^{3}	33^{0}
19	31^{0}	31^{1}	31^{2}	31^{3}	32^{0}	32^{1}	32^{2}	32^{3}	33^{0}	33^{1}
20	31^{1}	31^{2}	31^{3}	32^{0}	32^{1}	32^{2}	32^{3}	33^{0}	33^{1}	33^{2}

Length taken as in Fig. 1 to nearest quarter-inch above.

SHOULDER-FAT (10 Points) AND LOIN-FAT (20 Points)

Shoulder-fat is measured to the nearest $\frac{1}{16}$ in. at right angles to the skin at a point opposite the third vertebra. Loin fat is measured to the nearest $\frac{1}{16}$ in. at right angles to the skin at the smallest depth in the region opposite the kidney (see Fig. 1). For convenience, both these measurements include the thickness of skin, for which due allowance has been made in the tables. As a guide to the standard asked for, maximum points are awarded for shoulder-fat where this is between $\frac{22}{16}$ in. and $\frac{25}{16}$ in. in a pig of 141 lb. to 150 lb. Thus a small tolerance in fat-measurements at the shoulder is permitted for maximum points. At the loin the standard for a pig of the same weight is $\frac{14}{16}$ in., with no tolerance. Since the trade demands an *optimum* amount of fat, deductions are made (see Tables 2 and 3) for both increases and decreases in fat-measurements above and below these standards.

Table 2.—Scale of Points for Shoulder-fat
(Measurements, in sixteenths-inches, to include skin depth)

Points.	Weight (Lb.).				
	121–130.	131–140.	141–150.	151–160.	161–170.
1	33	34	35	36	37
2	32	33	34	35	36
3	31	32	33	34	35
4	30	31	32	33	34
5	29	30	31	32	33
6	28	29	30	31	32
7	27	28	29	30	31
7	26	27	28	29	30
8	25	26	27	28	29
9	24	25	26	27	28
10	23	24	25	26	27
10	22	23	24	25	26
10	21	22	23	24	25
10	20	21	22	23	24
9	19	20	21	22	23
8	18	19	20	21	22
7	17	18	19	20	21
7	16	17	18	19	20
6	15	16	17	18	19
5	14	15	16	17	18
4	13	14	15	16	17
3	12	13	14	15	16
2	11	12	13	14	15
1	10	11	12	13	14

Table 3.—Scale of Points for Loin-fat
(Measurements, in sixteenths-inches, to include skin depth)

Points.	Weight (Lb.).				
	121–130.	131–140.	141–150.	151–160.	161–170.
6	5	6	7	8	9
9	6	7	8	9	10
12	7	8	9	10	11
14	8	9	10	11	12
16	9	10	11	12	13
18	10	11	12	13	14
19	11	12	13	14	15
20	12	13	14	15	16
18	13	14	15	16	17
16	14	15	16	17	18
12	15	16	17	18	19
9	16	17	18	19	20
6	17	18	19	20	21
4	18	19	20	21	22
2	19	20	21	22	23

BALANCE AND DEPTH OF SIDE. (10 Points)

In view of the importance of this character in a bacon pig (see Fig. 2), attention has been given to the best way of measuring it. A good side is one which is not only well balanced in its proportions, but also one which is not too deep through the fore end. The method used hitherto has been to take the difference between the maximum depth through the chest and the depth through the flank. The smaller the difference, the greater the number of points awarded. This has not proved satisfactory, since short, excessively deep pigs often scored full marks. A little thought emphasizes that the depth of side should be considered in relation to its length. Accordingly, in the

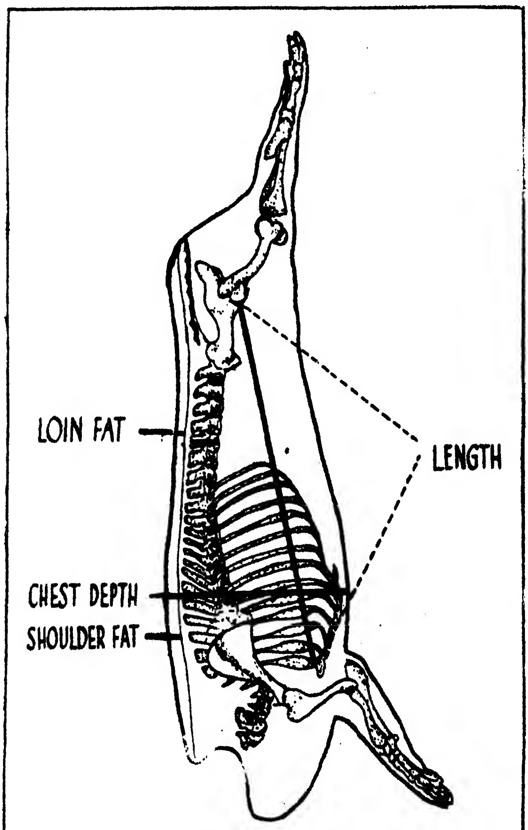


FIG. 1.—Method of measuring length, chest depth, shoulder-fat, and loin-fat.

system here adopted, the carcass is measured through the deepest part of the chest to the nearest $\frac{1}{8}$ in. (see Fig. 1), and points awarded according to the ratio of this measurement to the length of the same carcass.

For maximum points the chest depth must not be more than 40 per cent. of the length. Thus a pig with a length of 30 in. from aitch-bone to first rib will secure full points for balance and depth if it has a chest depth of 12 in. or less. An increase of $\frac{1}{4}$ in. above this standard results in a loss of 1 point (see Table 4). This standard is based upon the relationship between length and depth in the best-quality Danish Wiltshire sides(2).

TABLE 4.—SCALE OF POINTS FOR BALANCE AND DEPTH OF SIDE
(In eighth-inches)

Points.	Length, in Inches.							
	26.	27.	28.	29.	29.	30.	31.	32.
1	12^{6}	13^{1}	13^{4}	13^{7}	14^{2}	14^{5}	15	15^{3}
2	12^{4}	12^{7}	13^{2}	13^{5}	14	14^{3}	14^{6}	15^{1}
3	12^{2}	12^{5}	13	13^{3}	13^{6}	14^{1}	14^{4}	14^{7}
4	12	12^{3}	12^{6}	13^{1}	13^{4}	13^{7}	14^{2}	14^{5}
5	11^{6}	12^{1}	12^{4}	12^{7}	13^{2}	13^{5}	14	14^{3}
6	11^{4}	11^{7}	12^{2}	12^{5}	13	13^{3}	13^{6}	14^{1}
7	11^{2}	11^{5}	12	12^{3}	12^{6}	13^{1}	13^{4}	13^{7}
8	11	11^{3}	11^{6}	12^{1}	12^{4}	12^{7}	13^{2}	13^{5}
9	10^{6}	11^{1}	11^{4}	11^{7}	12^{2}	12^{5}	13	13^{3}
10	10^{4}	10^{7}	11^{2}	11^{5}	12	12^{3}	12^{6}	13^{1}

NOTE.—½ in. or over in length is to be counted as nearest inch above—*i.e.*, 28½ in. = 29 in. Depth to nearest eighth-inch above.

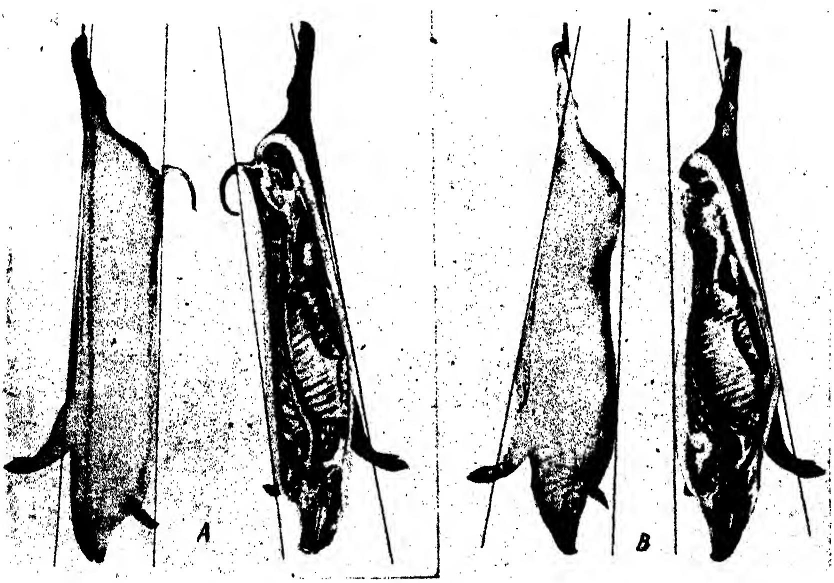


FIG. 2.—Balance of side: A, good balance; B, bad balance.

To avoid the danger of breeding pigs that are too shallow in chest depth a penalty of 5 points is deducted from the score for this character in the case of pigs that are 1 in. or more below the minimum chest depth standard for full points.

HAMS. (15 Points)

To aid judges in securing uniformity in awarding points for hams, photographic standards have been prepared (see Fig. 3).

The most important point is width through the thighs at the tail level when viewed from the back and depth when viewed from the side. The ham should also be well filled in the crutch, with short legs, carrying a maximum of fleshing down toward the hock.

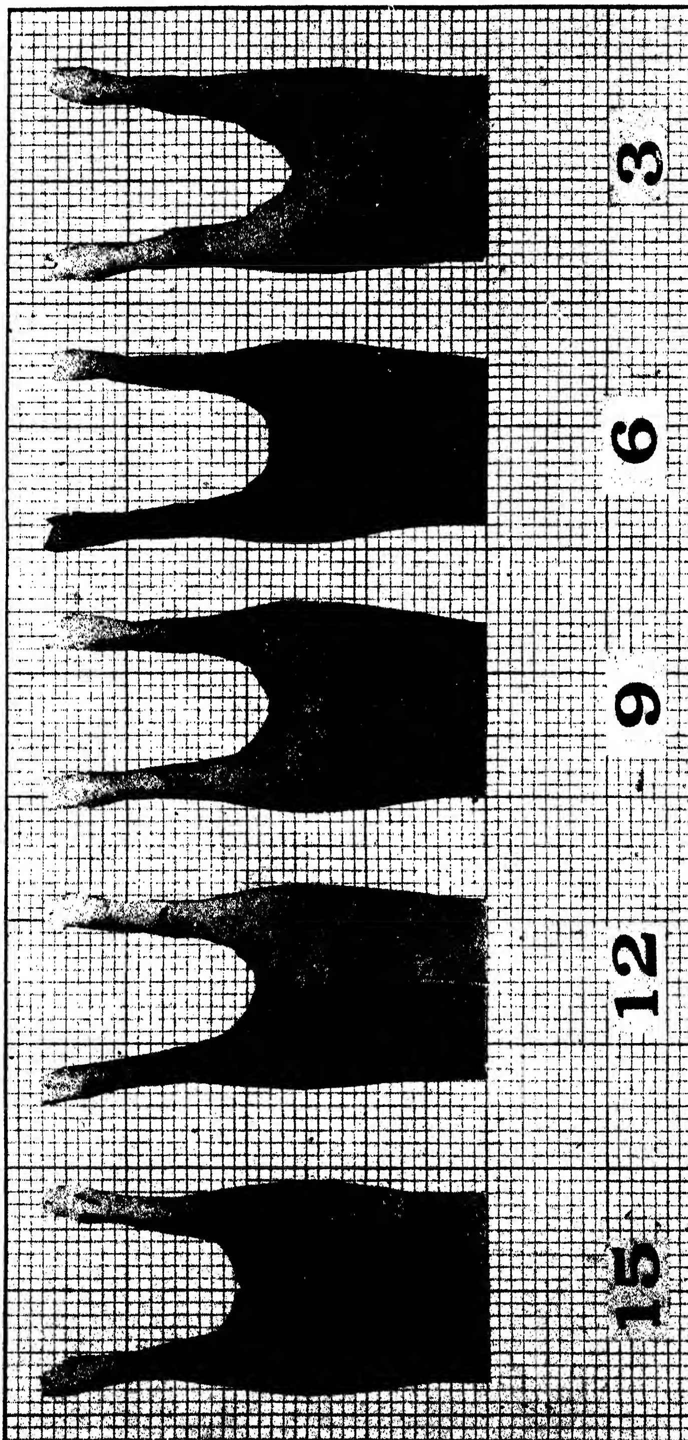


FIG. 3.—Photographic standard for judging hams.

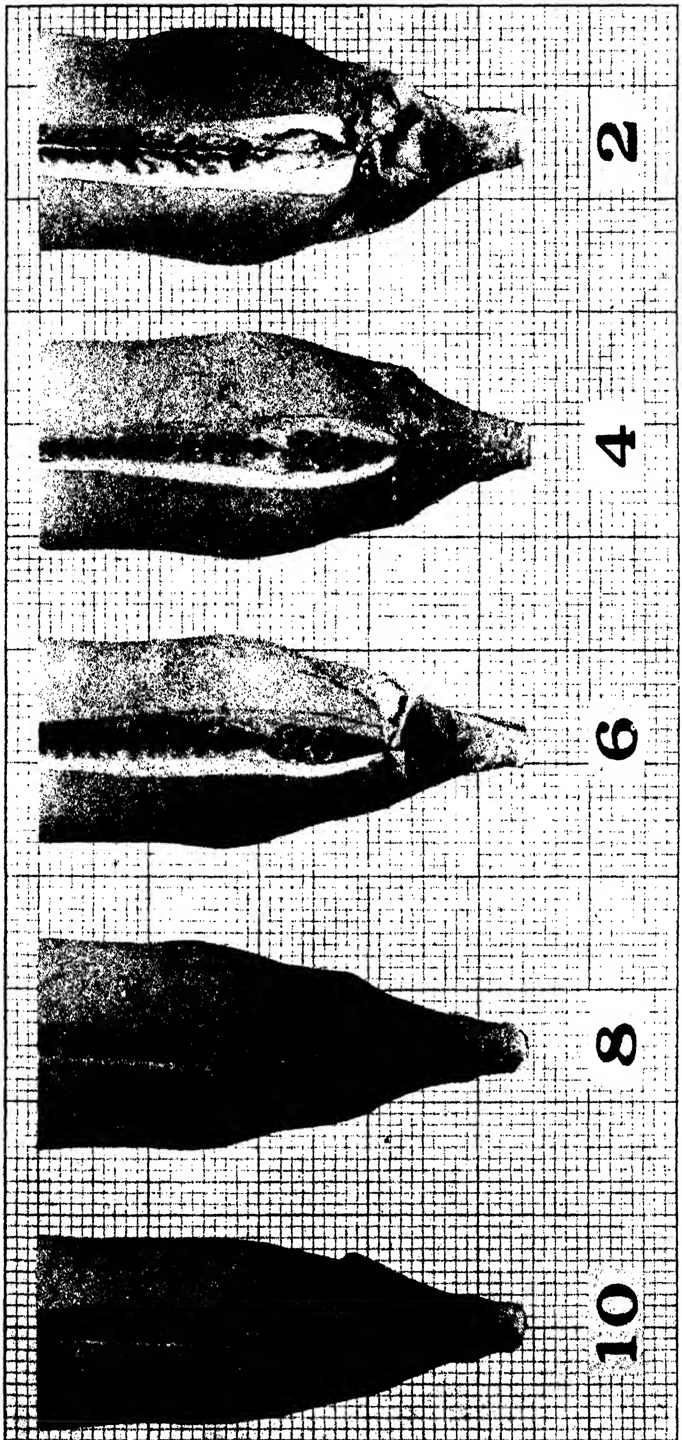


Fig. 4.—Photographic standard for judging fore end.

It is extremely important that this deep fleshing over the pelvis should consist of muscle rather than fat. Many hams have an ideal shape in being even wider, deeper, and better filled than that illustrated as being worthy of full points (Fig. 3), but are undesirable because these qualities come from excessive fat. Such hams must be penalized according to their degree of fatness.

It is also extremely important in this, as in all other eye-judgment characters, to make full use of the scale of points available. Most judges have a tendency to give neither very high nor very low points, with the result that fair allowance for ham quality is not made.

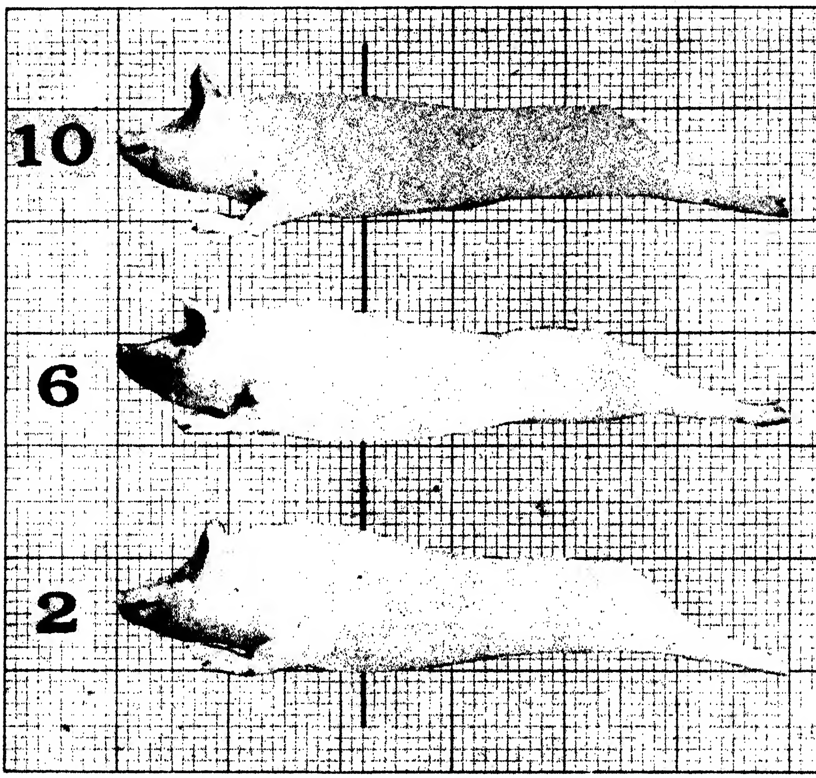


FIG. 5.—Further photographic standard for judging fore end.

FORE END (SHOULDERS). (10 Points)

Here again photographic standards have been provided to assist judges (Figs. 4, 5, and 6).

The principle that the fore end should account for the smallest possible weight of the whole carcass should dominate award of points. In general, this principle is fulfilled with a shoulder that is narrower across the back than the corresponding measurement through the hams; a shoulder that is neatly tapering rather than bulging, and a shoulder that is not too deep when viewed from the side. A slight bulge in the position of the shoulder-blade is not a defect if this is due to muscle rather than fat. This can usually be assessed by the depth of back muscle exposed by the backing down over the shoulder region. Head and jowl should be light. The side view (Fig. 5) is most important in assessing the relative weight of carcass in front and behind the shoulder-blade.

It must be emphasized that the shoulder can be too fine or sharp over the withers. Such excessive fineness is associated with lack of depth in fleshing throughout the carcass.

The same remarks about using the full scale of points in eye-judgments apply to judging the fore end.

Fullness of Meat. (10 Points)

In awarding points for fullness of meat, points are given for the wealth of muscle against fat. A reasonable proportion of fat is essential in all meat, but the average consumer insists on a much greater percentage of muscle than fat. In addition, he prefers a deep layer of muscle over the bone.

The committee appreciates that the only accurate measure of muscle depth is one obtained from cutting the carcass. Since this is not practicable an attempt to assess it by eye must be made. Because any such assessment

Fig. 6.—Examples of good and bad balance in the cured side.

can be no more than an educated guess, fewer points are awarded for this character than under the Smithfield system, where the actual depth of eye-muscle on the loin cut was used as a basis.

Since the loin region is the weakest part of a pig, the development in this part is taken as a guide. Fullness of meat is judged according to the fullness of loin, taking into account the thickness of fat-cover. From careful comparisons of uncut and cut loins it is considered that the depth of muscle will be satisfactory providing the loin region is well developed and providing this development is not made up mostly of fat. Evenness of fat-cover is essential. The depth of fat may be correct in the back line over the loin but thicken very quickly a few inches down the side. Such a loin appears very well " filled " to the inexperienced judge. This is not so. The correct type of loin is flat and wide on the back, with the sides almost square with the back and not round like a barrel. This generally gives a definitely " feminine waist " to a pig to a degree which amounts to weakness according to traditional standards (see the good pig of Fig. 7).

A secondary guide which must also be taken into account is the thickness of belly in the loin region. The greater the thickness, providing again that this is not due mainly to fat, the greater the points awarded.

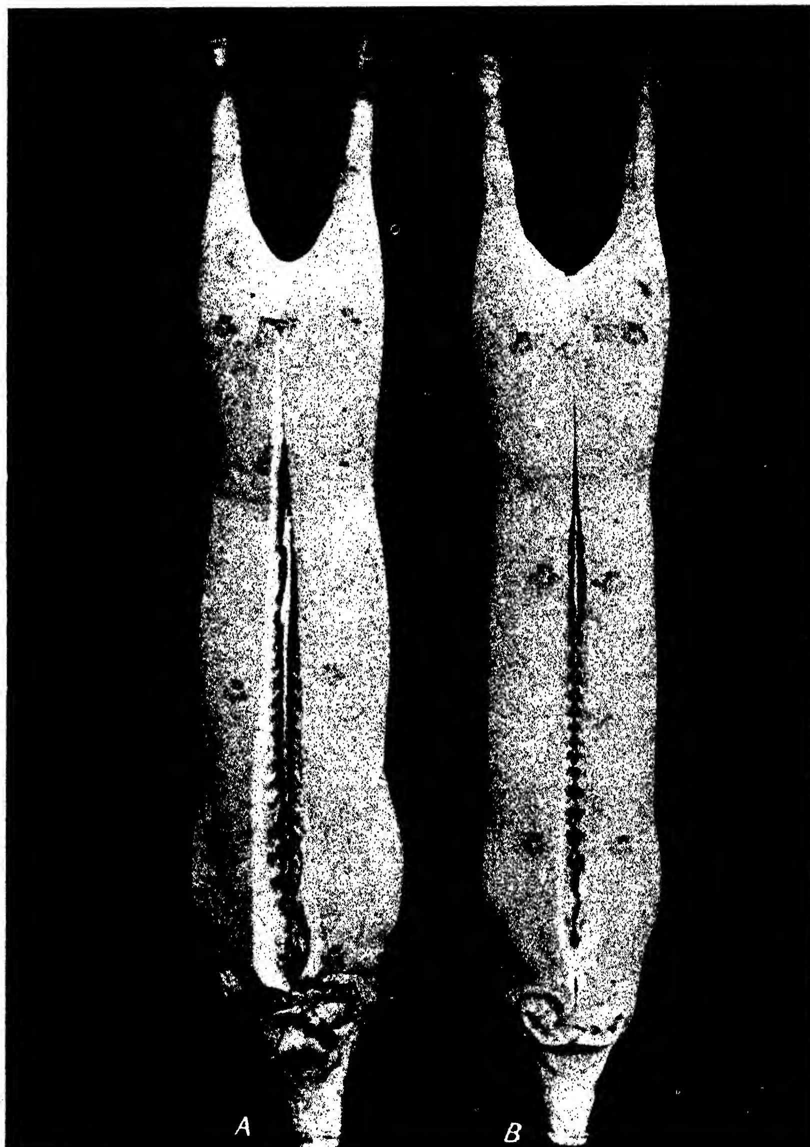


FIG. 7.—Good and bad proportioned pigs: A, heavy fore end and light hind end—bad type; B, heavy hind end and light fore end—good type.

Experience on the part of judges is more essential in judging fullness of meat than in any other character.

Marketing Points. (5 Points)

This allowance is made to take into account those characters important to the trade which have not been included above.

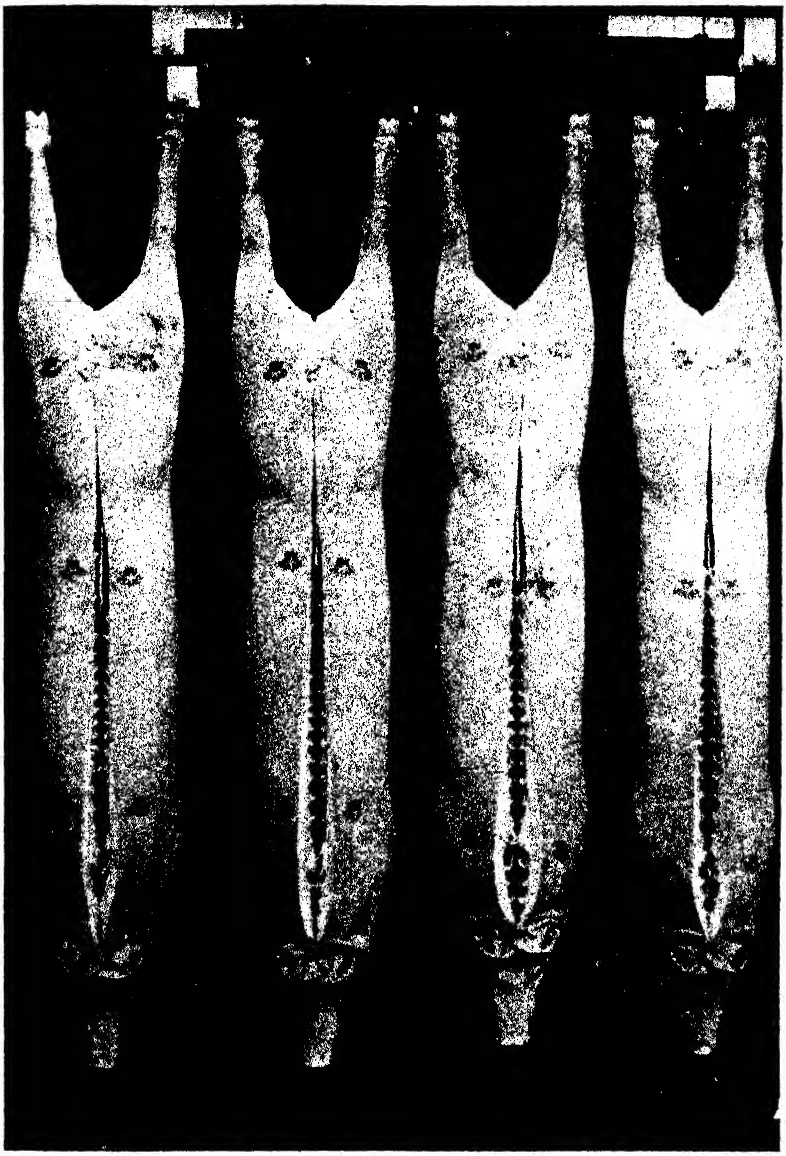


Fig. 8.—The type of pig the system is designed to select. This group won the 1944 Fletcher Competition with an average mark of 78½ points.

Under this heading are considered texture and colour of skin, freedom from hair, bruises, and blemishes, and suitability of weight.

Texture and Colour of Skin.—The skin must be thin and fine in texture. It must also be uniformly light in colour. Deviations from these requirements are penalized by loss of points.

Freedom from Hair, Bruises, and Blemishes.—These are self-explanatory, with the proviso that no penalty is made for bruises or abrasions which, in the opinion of the judges, have been incurred in transit.

Weight Suitability.—In view of the recommendation already made to confine carcass competitions to pigs of true bacon weight, and to ensure that pigs below 130 lb. do not gain an advantage if they have to be included, penalties are made for unsuitability of weight. The judge should exercise his discretion here and make whatever deduction, up to the full value of 5 points, that is necessary to exclude such a pig from a high rating.

JUDGING OF GROUPS OF PIGS

The foregoing system is designed to apply to the evaluation of a single pig. For many reasons, different organizations are interested in competitions involving more than one pig per entry, and are faced with the problem of adapting a judging system to a group of pigs.

The committee is of the opinion that any special additions to the method so far outlined, to suit such competitions, are the responsibility of the organization involved and should be decided on a basis of the particular objectives of the competition concerned.

As a general guide, however, the committee, based on its experience of such group competitions, makes the following recommendations:—

(1) That the individual pigs be judged as above, and the total score of the group obtained and used as the basis of award:

(2) That, in addition to individual quality, allowance be made for uniformity of both weight and type on a group basis:

(3) Uniformity of weight (10 points) should be allowed for according to the difference in weight between the lightest and heaviest member of the group, as follows:—

Weight Range.	Per Group.
10 lb. or less	10 points.
14 lb.	8 points.
18 lb.	6 points.
22 lb.	4 points.
26 lb.	2 points.

This scale can apply irrespective of the number of pigs in the group:

(4) Uniformity of type should be allowed for on a basis of 10 points per group for evenness of conformation as judged by eye. Thus the group of Fig. 8 would secure 9 points, losing 1 point for the short carcass. The total points here might well be reduced to 5 for groups involving less than four pigs.

(5) Disqualification of one pig in a group should automatically disqualify the whole group.

ACKNOWLEDGMENTS

The thanks of the committee are due to the Department of Agriculture, Messrs. W. and R. Fletcher and Co., Ltd., and the Auckland Farmers' Freezing Co., Ltd., without whose co-operation the investigation on which this report is based would not have been possible. We also appreciate the action of the National Pig Industry Council and the New Zealand Pig Breeders' Association in accepting the system as the official standard judging system for bacon pigs.

REFERENCES

(1) DAVIDSON, H. R., *et al.* (1936): *Pig Breeders Ann.*, *16*; 49–69.
(2) MCMEEKAN, C. P. (1939): *J. Agr. Sci.*, *29*, 116–124.

FLUE-CURED TOBACCO

I. CHANGES IN WEIGHT OF LEAF DURING CURING

By H. O. ASKEW and R. T. J. BLICK, Cawthron Institute, Nelson

[*Received for publication, 28th August, 1944*]

Summary

Tobacco-leaves when flue-cured suffer a progressive loss in weight due mainly to loss of moisture. In the earlier stages the mid-rib loses weight more rapidly than the blade, but later on the blade loses weight at the greater rate.

It is apparent that curing of leaf is possible over a range of temperatures and a wide range of relative humidities in the kiln, particularly in the "colouring" stage. Rate of loss of weight in this first stage is largely governed by the temperature and relative humidity of the air in the kiln.

During the curing process there occurs a loss of dry matter amounting to 12 to 17 per cent. of that originally present. This loss is associated with the "colouring" stage—that is, during the first thirty-six to forty-eight hours.

Leaf picked from different parts of the plant behaves in an essentially similar way, although the percentage of dry matter is higher in the fresh leaf from the top of the plant.

INTRODUCTION

THE curing of tobacco to produce an article acceptable to the smoking public is a highly specialized operation during which a number of chemical changes take place in the leaf. In spite of the magnitude of the flue-curing of tobacco in the United States of America and other countries there does not appear to be a great deal of information in the literature covering the scientific side of flue-curing.

With the object of observing the changes occurring during the flue-curing of tobacco in New Zealand, a series of experiments to follow the changes in weight and in chemical composition of the leaf, were planned. To date eight curing trials over two seasons have been completed. In the present paper the weight relationships of the leaf are described, the chemical data being reserved for a later paper.

EXPERIMENTAL

Harrison's Special variety was grown at the Tobacco Research Station, Umukuri, with the ready co-operation of Mr. R. Thomson, the Director of the Station, in two seasons, 1942–43 and 1943–44. In the former season three trials were carried out, and in the latter season five trials were completed. The series of five trials covered all pickings of mature leaf from the plants except the first, and thus presents a picture of the behaviour of the leaves on different parts of the plant.

The plants of the 1943–44 season were set in the field on 25th November, 1943, 2 ft. apart in rows 3 ft. 6 in. wide, and received a 3·8–8 mixed fertilizer at the rate of 1,000 lb. per acre, half being sown in the rows before planting and the other half being given as a side dressing on 16th December, three weeks after planting. In the 1942–43 season the plants received a similar fertilizer treatment. The spring months (September to November) of the 1942–43 season were drier than usual, but good rains fell in December. During the ripening period of the leaf February was very wet (6·27 in.), but March was very dry (0·15 in.). The 1943–44 season was not a very satisfactory one, being cold and wet in the spring, followed by a long dry

period in early summer, during which irrigation of the plants was resorted to on 7th and 20th January, 1944. Later on very satisfactory falls of rain occurred, leading to excellent growth of the plants. During the harvesting season further frequent, sometimes heavy, falls of rain were recorded. Removal of the leaves beginning at the bottom of the plant, as they became ripe, "priming," was employed in harvesting, two or three leaves being removed at a time.

In 1942-43 the three experiments were commenced on 18th February, 4th March, and 11th March, while the five trials of the 1943-44 season began on 15th and 24th February and on 7th, 17th, and 22nd March. The second season's trials were carried out with material from successive pickings from the same plot of plants. The method of carrying out the experiments was as follows: from a bin of harvested leaves lots of leaf were "tied" on twelve "sticks," thirty-two leaves to a stick tied in twos in the first season, and forty-eight leaves to a stick tied in threes in the second season. Weights of leaves on the sticks were recorded. These sticks were then placed in a kiln and cured under ordinary conditions, a stick being removed every six hours at some stages and later at twelve-hour- or twenty-four-hour intervals. A similar sample of leaves was taken at the beginning of each trial for immediate drying in the laboratory to obtain the basic data of moisture content. On removal from the kiln the stick of leaves was weighed at once, and later the leaves were removed from the stick and taken to the laboratory for rapid drying. They were then ground and their residual moisture content determined. From these data the amount of dry matter in the leaf could be calculated. Wet and dry bulb thermometers were placed among the experimental leaves and records of the thermometer readings were made whenever leaves were removed from the kiln. In most cases temperatures were also recorded by a thermograph, the thermometers of which were located approximately in the centre of the kiln. Temperatures and relative humidities corresponding to the times of removal of the samples from the kiln are given in the tables of data (see Appendix).

A brief outline of the process of curing may be helpful in following the data in the tables of this paper. In the first stage, "colouring," the leaf is held at 80-90° F. under high relative humidity conditions with little ventilation of the kiln. The leaf is thus allowed to respire under mild humid conditions, during which time the chlorophyll in the leaves is largely destroyed and the yellowing colouring matters, which were previously masked by the chlorophyll, become visible. Other chemical changes also take place. This stage may take from thirty-six to forty-eight hours. Later the temperature is raised and the humidity reduced to "fix" the colour, which should be a clear yellow. Practically no further changes in colour now take place, and the temperature is such that the vital processes active during the "colouring" stage are no longer operative. Later the temperature is still further increased and the humidity further reduced, with consequent rapid loss of weight of the leaf due to drying-out of the blade and midrib. By the time the latter is sufficiently dry the temperature will have been increased to, and maintained at for some hours, 160-170° F. The relative humidity will be low. These stages of curing are shown in a somewhat idealized form in Fig. 1, but it must be understood that the lengths of time any one lot of leaf is maintained under a certain set of conditions will not necessarily be the same as given in the diagram. Operation of the kilns is a highly skilled occupation, the person in charge being required to vary the conditions according to his estimate of the manner in which the leaf is curing. No closely defined set of conditions can therefore be laid down which will lead to a satisfactory cure of all types of leaf.

1942–43 Season

As has already been stated, three experiments were made in this season. Of these, the first was with leaf taken just above the middle of the plant, the average fresh weight being 39·4 g. and the dry weight 5·95 g. Temperature and relative humidity conditions were fairly constant at 85–88° F.

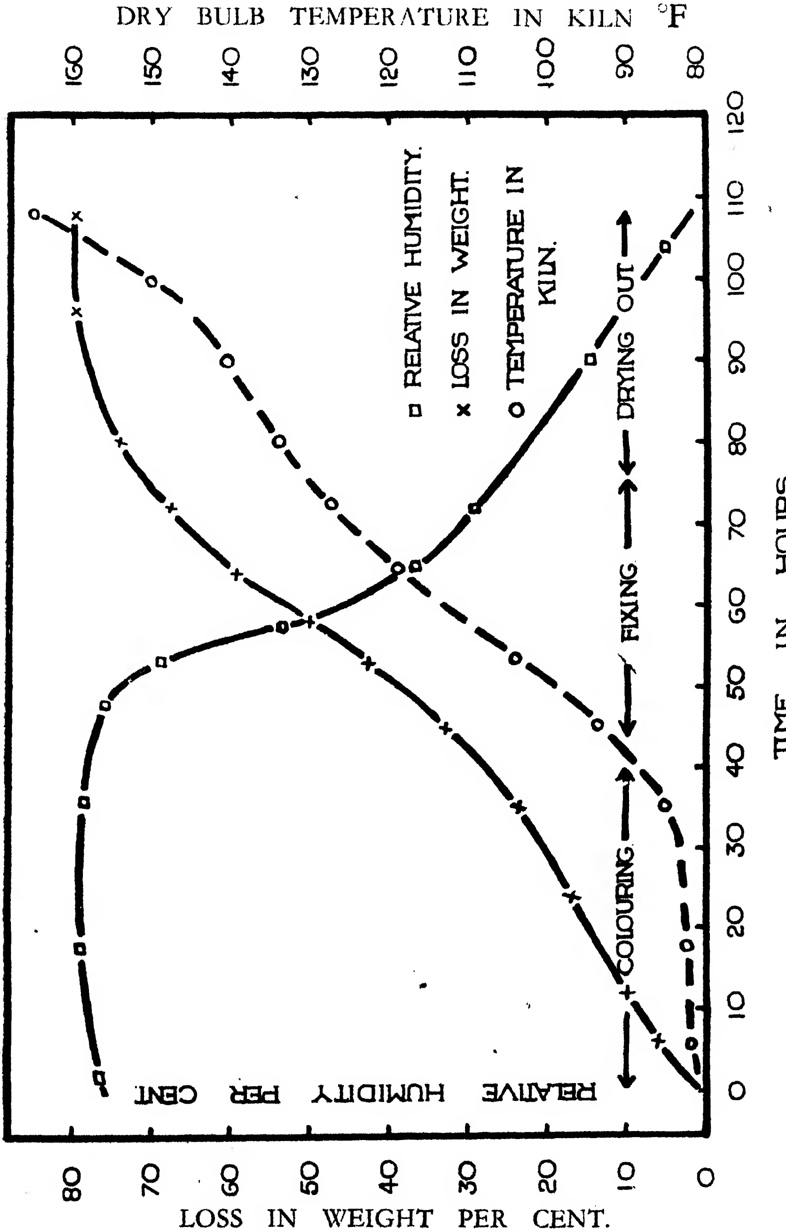


Fig. 1.—Curves showing relationships of loss of weight of leaves and temperature and relative humidity in kiln during flue-curing of tobacco.

and 84–92 per cent. respectively for the first thirty-six hours, with a small loss in weight of the leaf (approximately 20 per cent.). The final figure for loss in weight was 84·9 per cent., the temperature being 170° F. In the second trial the leaf was picked from higher up the plant, the average fresh weight

being 36·7 g. and the dry weight 6·36 g. It will be noted, therefore, that the latter leaves had a dry-matter content of 17·4 per cent., as against 14·8 per cent. for leaves of the former experiment; this is a normal variation for leaves from different parts of a tobacco-plant. In this second experiment the dry-bulb temperatures were about the same as in the first experiment, but the relative humidity was lower during the colouring stage (70–79 per cent.), with resultant greater loss in weight (29 per cent. after thirty-six hours). When curing was completed the over-all loss in weight was 79·5 per cent.

These preliminary experiments therefore showed that rate of loss of weight might vary between different kilns of leaf with variation in the temperature and relative humidity conditions.

1943–44 SEASON

The 1943–44 series consisted of five trials in which successive harvests of leaves from the same plot of plants were taken. In Table I a summary is given of the average fresh and dry weights and percentage of dry matter in the various lots of leaf. Two "sand" leaves had been removed before the experiments began.

TABLE I.—WEIGHT OF LEAVES AND DRY-MATTER CONTENT

Experiment.	Fresh Weight.	Dry Weight.	Dry Matter.
	g.	g.	Per Cent.
A (lower leaves)	58·5	8·09	13·83
B	64·1	9·41	14·68
C	45·5	8·04	17·69
D	36·0	6·97	19·35
E (top leaves)	28·9	5·52	19·06

Experiment B had the largest leaves. It is generally recognized that the best-quality leaves come from about the second main pick on the plants. In passing toward the top of the plants the leaves get smaller and more elongated and show higher dry-matter contents, and produce a lower grade of tobacco.

WEATHER CONDITIONS

In Table II are given the maximum and minimum air temperatures at the Tobacco Research Station for the days on which the leaf was harvested and for the succeeding forty-eight hours covering the colouring period in the kiln (control of the kiln is affected to a considerable extent by the outside air temperatures). Temperatures for the first three experiments were somewhat higher than for the last two. In each case the leaf was harvested when the day of picking was fine and at least one previous day had also been fine. The leaf was never wet with rain or dew when harvested. Rainfall was at times heavy, as is seen by the amounts registered for the periods between harvests.

TABLE II

Experiment.	Outside Air Temperatures.		Rainfall.	Weather.
	Maximum.	Minimum.		
	° F.	° F.	In.	
A	73–76	49–52	0·36*	Fine for two days.
B	70–80	55–56	4·24	Fine for three days.
C	74–76	52–53	0·27	Fine for four days.
D	57–65	39–51	4·06	Fine for two days.
E	67–68	43–44	1·21	Fine for two days.

* Two days previous to picking.

TEMPERATURE AND RELATIVE HUMIDITY CONDITIONS IN THE KILN

During the experiments records of wet and dry bulb temperatures were taken when each sample of leaves was removed from the kiln. These were used to calculate the relative humidity. Two of the three kilns used for the experiments were equipped with Cambridge recorders for wet and dry bulb temperatures. Comparison of the individual readings given in the tables of the Appendix to this paper with those on the thermograph charts shows that in most cases the samples were removed at periods when the temperature had been constant for some hours. It was only very occasionally that the sampling time coincided with a period during which the temperature was being raised, in passing from the colouring to the fixing stage.

An analysis of the temperatures and relative humidities recorded in the tables shows that in the colouring stage the temperatures varied in different experiments over as much as a 10-degree range (*e.g.*, in experiment B the range was from 82 to 92° F.); in others the range was smaller and the temperatures lower (*e.g.*, experiment C, range 79 to 85° F.). There was also a large variation in relative humidity, the extreme values recorded being 68 and 100 per cent. In some of the experiments the relative humidity was low, while in others a wide range was observed although it was high throughout (*e.g.*, experiment D, range 80 to 100 per cent.). These data therefore show that no constant figures can be conveniently set for the conditions of curing with the present design and method of operating a commercial-sized kiln even under expert supervision.

In the second, or fixing, stage the range of temperatures has been from 100° F. to 140° F., with fairly constant minimum and maximum figures. Relative humidity has varied considerably from one experiment to another at a stated temperature; for example, at 110° F. in experiments D and E the respective relative humidities were 37 and 70 per cent. In the final stages at 130° F. to 140° F. the relative humidities have ranged from 21 to 49 per cent.

In the drying-out stage the differences in temperatures of the several experiments are fairly small, all experiments finishing at 160° F. The relative humidity was in all cases 20 per cent. or less.

LOSS IN WEIGHT OF THE LEAVES

The full data for loss of weight and derived data are given in Tables A to E of the Appendix. Figure 2 shows the loss of weight data in graphical form. From this diagram it is seen that, although the general shapes of the curves are the same for each experiment, there are considerable variations in percentage loss of weight after a given period of time in the kiln. Irregularities in the curves, particularly within the first forty-eight hours, can be correlated with variations in the temperatures and relative humidities reported in the tables. Losses of weight are not large in the "colouring" stage, but increase rapidly during "fixing" and in the first stages of drying out the blade and midrib. The low rate of loss towards the end of curing is due to the slow removal of the small amounts of water left mainly in the midrib. By the time curing was completed 82 to 85 per cent. of the original weight of the leaf had been lost.

MOISTURE CONTENT OF LEAF AT DIFFERENT STAGES OF CURING

From the data obtained the moisture content of the leaf at the different stages can be calculated. The most interesting stage is the "colouring" because here the leaf is still sufficiently moist and at a sufficiently low temperature to permit many vital processes to operate, although the leaves have been removed from the plant. Calculation shows, in confirmation of

the statement of Ward(1), that in the colouring stage the moisture content is relatively constant, especially where the temperature and relative humidity have been held at nearly constant values. This constancy of moisture content is found even when appreciable losses of weight have occurred.

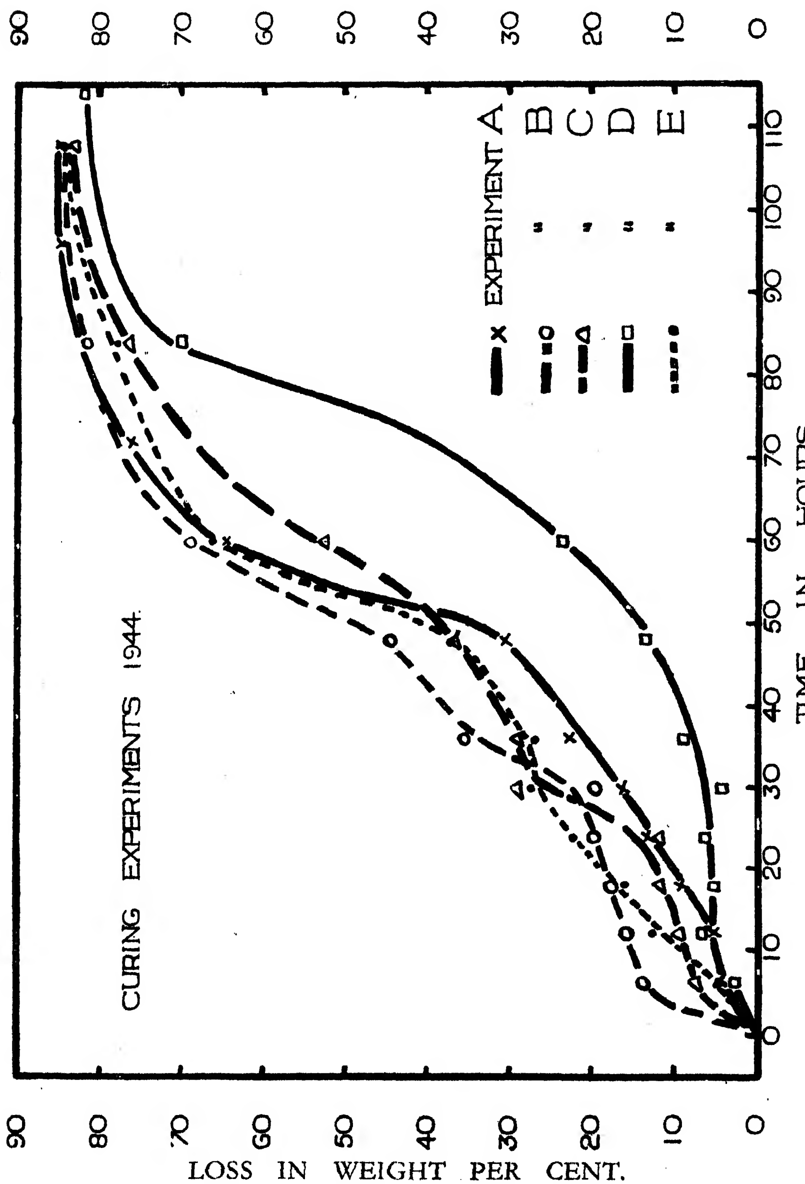


FIG. 2.—Losses of weight of tobacco leaves during flue-curing.

Once the later stages of curing have been entered the moisture content of the leaf decreases rapidly until by the time curing is completed little or no moisture may remain, particularly in the blade of the leaf, although the midrib may contain an appreciable percentage (see later section).

If the data for loss of weight during colouring are plotted as logarithms (to base 10) against time in hours straight-line graphs are found, as was also observed by Vickery *et al.*(2) for air-cured leaf. This relationship seems to be fairly general, because putting the data of other workers into this form also leads to similar conclusions. The interpretation of this relationship is that the loss of weight is proportional to the moisture remaining in the leaf at any given time.

Loss of Weight of Midrib and Blade of Leaves during Curing

A matter of interest and of importance in curing is the possible difference in the rate of drying of the blade and midrib of the leaf. In 1943 (experiment III) an attempt was made to apportion the losses of weight and other changes in the leaf between the blade and the midrib, details of the experiment being reported in Table III. After each sample was weighed on removal from the kiln the midribs were removed from the leaves, the blades and midribs then being dried separately in the laboratory to get their dry weights. Losses of weight are shown in Table III for the whole leaf, for the blades, and for the midribs, when it is seen that in the early stages of curing the midribs lost weight at a faster rate than the blades. After sixty hours, however, the blades lost a greater percentage of their weight than did the midribs, and by the time curing was completed the blades and midribs had lost 80·0 and 78·5 per cent. respectively of their original weights. In Fig. 3, where these changes are shown in graphical form, the curve for the whole leaf lies between those for the blade and midrib and nearer to that of the former because the blade in this sample formed two-thirds of the original weight of the leaf. It is noteworthy, too, that at completion of curing the blade was apparently completely dry while the midribs still contained an appreciable percentage of moisture.

TABLE III.—DATA FOR CURING EXPERIMENT III STARTED 11TH MARCH, 1943

Part of Leaf.	Hours in Kiln.	Loss of Weight.	Moisture in Sample.	Dry Matter.	Loss of Dry Matter.	Temperature in Kiln. Dry Bulb.	Wet Bulb.	Relative Humidity.
		Per Cent.	Per Cent.	Per Cent.	Per Cent.	F.	F.	Per Cent.
Midrib ..	0	..	88·3	11·7	..	..	..	..
	12	24·2	81·7	13·9*	0·0	83	..	..
	36	40·1	79·7	12·1	12·6	85	76	64
	60	43·7	78·1	12·3	11·5	89	81	69
	84	53·4	73·6	12·3	11·6	116	92	40
	108	74·5	52·9	12·0	13·7	135	..	..
	132	78·5	44·2	12·0	13·7	172	..	..
Blade ..	0	..	77·2	22·8	..	..	..	..
	12	18·4	72·4	22·5*	0·0	83	..	..
	36	30·0	69·4	21·4	4·7	85	76	64
	60	45·3	65·5	18·9	16·0	89	81	69
	84	70·0	36·0	19·2	15·4	116	92	40
	108	79·5	10·4	20·5	15·5	135	..	..
	132	80·0	0·0	20·0	11·1	172	..	..
Whole leaf ..	0	..	80·9	19·1	..	..	..	..
	12	20·3	75·4	19·6	0·0	83	..	..
	36	33·3	72·4	18·4	6·3	85	76	64
	60	44·8	69·7	16·7	14·7	89	81	69
	84	64·5	52·3	16·9	13·7	116	92	40
	108	77·9	24·7	16·7	14·8	135	..	..
	132	79·5	15·2	17·3	11·5	172	..	..

* Used for calculation of loss of dry matter.

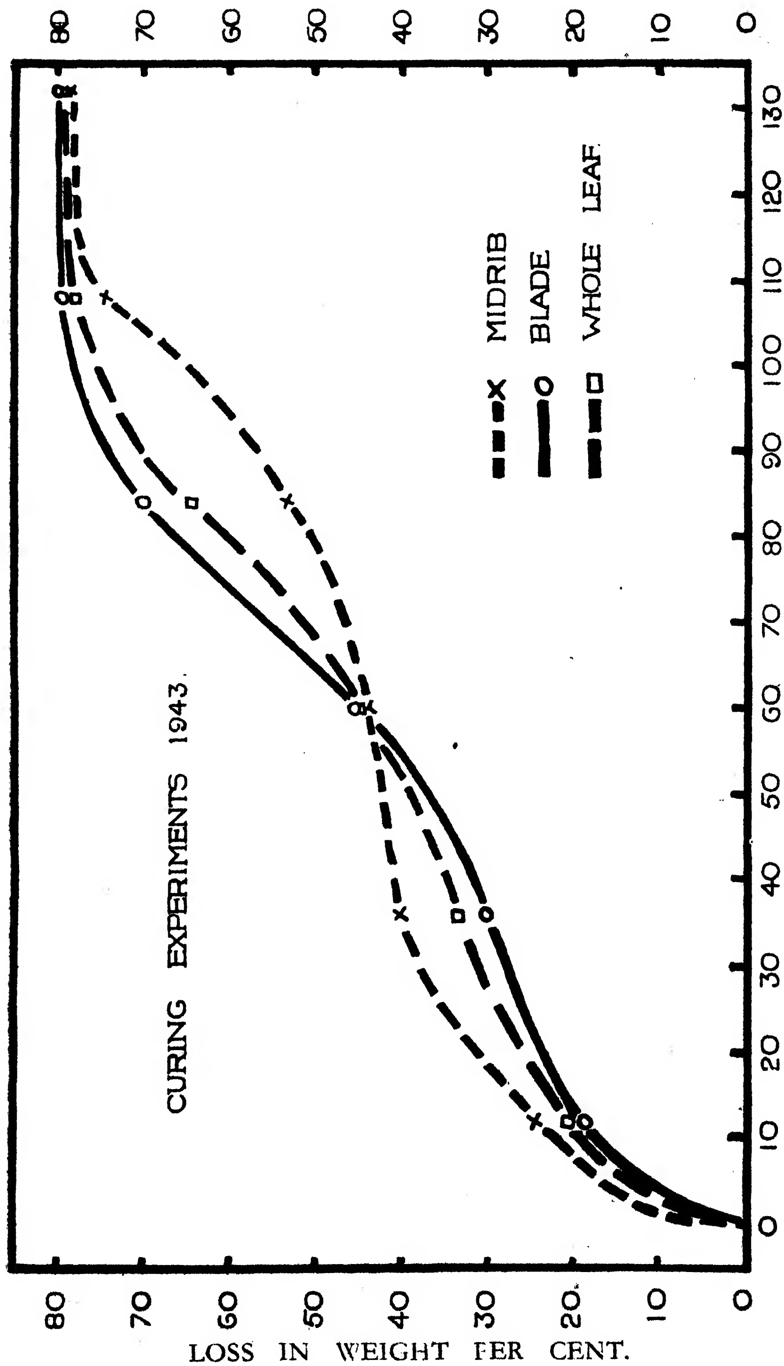


FIG. 3.—Losses of weight of whole leaf, blade, and midrib of tobacco-leaves during flue-curing.

Loss of Dry Matter of Leaves during Curing

When the calculations of dry-matter content were being made in connection with the first season's experiments it was noticed that there was apparently a considerable loss of dry matter during the curing operation. This loss has been confirmed in the second season's trials. Table 4 shows the results of such calculations. The dry-matter content of the samples on entering the kiln is given in the second column, and in the third column the yield of dry matter in the cured leaf calculated on the fresh weight of the sample is given. In the fourth column are given the average losses of dry matter as a percentage of that originally present for the period twenty-four to thirty-six hours in the kiln, and in the right-hand column 5 are given the average losses of dry matter from thirty-six hours to the end of curing.

Table IV.—Loss of Dry Matter during Flue-curing of Tobacco-leaf

Experiment.	Dry-matter Content.		Loss of Dry Matter*.	
	Before Curing.	After Curing.	Period Twenty-four to Thirty-six Hours.	After Thirty-six Hours.
(1)	(2)	(3)	(4)	(5)
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
A	13·8	12·0	12·2	14·0†
B	14·7	13·2	17·1	16·6
C	17·7	15·3	9·2	11·7
D	19·4	17·0	11·0	12·4
E	19·1	15·5	10·6‡	15·3
III blades	22·8	20·0	4·7†	14·5
III midribs	13·9	12·0	12·6†	12·6
III whole leaf	19·1	17·3	6·3†	13·7

* As percentage of dry matter present in the fresh leaf. † On a single determination.
‡ Average excluding one very low figure.

The data of Table IV, columns 2 and 3, show that the weight of cured leaf to be expected from the original dry-matter percentage is not realized. This is probably due to loss of dry matter through respiration of the leaves in the colouring stage. As indicated in column 4, the average loss of dry matter over the period twenty-four to thirty-six hours, which covers the latter portion of the colouring stage, is not greatly different from that given in column 5, which refers to the fixing and drying-out stages. In some cases there appear to be inconsistencies to this statement, but examination shows that in these sufficient points were not available for calculation of a satisfactory average figure. If there is any increase in loss of dry matter after thirty-six hours, that increase would appear to be small. From the above data it appears that 12 to 17 per cent. of the dry-matter in the leaves is lost during curing. There is no consistent trend to indicate that one type of leaf suffers a greater loss than another.

The data from experiment III indicate that there is no great difference between loss from the blade and from the midrib. The difference shown in Table IV may easily be due to experimental error.

DISCUSSION

The aim of the tobacco-grower is to produce a lemon-coloured leaf of uniform colour; this can only be done by constant attention to the kiln to ensure satisfactory temperature and humidity conditions within it. If the normal changes of curing are to take place, the leaf must be held for a time in a sufficiently moist condition and therefore the relative humidity must be high during the early stages(3). It would appear, however, from the data of the present series of experiments that a wide range of relative humidities will permit curing. It is not possible to say whether a particular range of humidity is more satisfactory than another for a particular type of leaf. A wide field of experimentation could be opened up to examine this question in detail.

In the present experiments it has not been possible to apportion the over-all loss of weight between loss of water and loss of dry matter. It would seem desirable that further work should be done to determine the proportions of the total loss at each stage due to loss of water and loss of dry matter.

A matter of importance in curing the leaf is to decide when the midrib is sufficiently dry, because excessive moisture content will cause the cured tobacco to become mouldy at a later date. From experiment III it would appear that the blade of the leaf may be completely dry when the midrib still contains an appreciable percentage of water. Data from other experiments reported in this paper indicate that in some cases the leaf may be completely dry at the end of curing (experiment D), while in other cases approximately 10 per cent. of moisture may be present. That moisture is still left in the leaf, after the curing was considered to be complete, was shown by two "snap" samples taken at random from kilns just before the fires were allowed to go out at the completion of curing; on the whole leaf basis moisture contents of 6·5 per cent. and 8·9 per cent. were found. It was not possible in these cases to separate blade and midrib before determining the moisture content. The proportion of midrib to blade may govern the final moisture content on the whole leaf basis. Here again it would appear that further work is desirable to examine more closely the moisture status of the leaf during the final stages of the curing process.

ACKNOWLEDGMENTS

The authors have great pleasure in thanking Mr. R. Thomson and his staff at the Tobacco Research Station for their ready help at all times in connection with these experiments. They also wish to thank Messrs. I. White and A. Oakly for help in the preparation of the samples.

REFERENCES

(1) WARD, G. M. (1942): *Tech. Bull. 37, Dept. Agr. Dom. Canada*, p. 44.
(2) VICKERY, H. B., *et al.* (1933): Pub. 445, Carnegie Inst. Wash., p. 10.
(3) COOPER, A. H., *et al.* (1940): *Ind. Eng. Chem.*, *32*, 194.

APPENDIX

TABLE A.—DATA FOR CURING EXPERIMENT A, STARTED 15TH FEBRUARY, 1944

Hours in Kiln.	Loss in Weight.	Moisture in Sample.	Dry Matter.	Loss of Dry Matter.	Temperature in Kiln.		Relative Humidity.	Remarks.
					Dry Bulb.	Wet Bulb.		
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	° F.	° F.	Per Cent.	
0	..	86·2	13·83	..	..	..	..	..
6	4·5	86·5	12·91	6·7	81	80	95	Temperature steady.
12	5·0	86·7	12·63	8·7	80	78	91	,,
18	9·1	86·3	12·44	10·0	81	78	87	,,
24	13·2	85·4	12·66	8·5	81	78	87	,,
30	16·0	85·3	12·05	12·9	84	83	96	,,
36	22·5	84·9	11·73	15·1	85	83	91	,,
48	30·2	83·0	11·89	14·0	108	102	81	Temperature rising.
60	64·6	..	..	..	125	93	30	Temperature steady.
72	76·0	..	..	..	133	99	30	,,
96	84·8	..	..	..	170	105	13	,,
108	84·8	..	..	..	170	100	10	,,

TABLE B.—DATA FOR CURING EXPERIMENT B, STARTED 24TH FEBRUARY, 1944

Hours in Kiln.	Loss in Weight.	Moisture in Sample.	Dry Matter.	Loss of Dry Matter.	Temperature in Kiln.		Relative Humidity.	Remarks.
					Dry Bulb.	Wet Bulb.		
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	° F.	° F.	Per Cent.	
0	..	83·3	14·68	..	..	..	..	..
6	13·7	83·3	14·44	1·6	82	75	71	Temperature steady.
12	15·5	82·6	14·66	0·2	83	76	71	,,
18	17·3	83·6	13·53	7·8	83	79	83	,,
24	19·7	85·5	12·21	16·8	92	86	77	,,
30	19·1	84·8	12·26	16·5	85	80	79	,,
36	35·3	81·4	12·06	17·9	87	79	69	,,
48	44·3	78·7	11·85	19·2	115	97	52	Temperature rising slowly.
60	68·9	61·6	11·96	18·8	114	101	63	Temperature steady.
84	81·7	34·4	12·00	18·2	143	..	..	,,
108	84·9	12·7	13·16	10·3	170	94	7	,,

TABLE C.—DATA FOR CURING EXPERIMENT C, STARTED 7TH MARCH, 1944

Hours in Kiln.	Loss in Weight.	Moisture in Sample.	Dry Matter.	Loss of Dry Matter.	Temperature in Kiln.		Relative Humidity.	Remarks.
					Dry Bulb.	Wet Bulb.		
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	° F.	° F.	Per Cent.	
0	..	82·3	17·69	..	..	..	..	..
6	7·2	82·2	16·52	6·6	85	76·5	66	Temperature steady.
12	9·1	83·1	15·38	13·0	79	74	78	,,
18	11·7	82·7	15·29	13·6	84	79	79	,,
24	12·0	81·5	16·27	8·0	82	78	83	,,
30	28·9	77·6	15·94	9·9	85	77	68	,,
36	28·9	77·5	16·00	9·6	82	75	71	,,
48	36·6	75·0	15·83	10·5	109	87	39	Temperature rising slowly.
60	52·4	68·0	15·22	14·0	115	87	30	Ditto.
84	76·5	31·4	16·13	8·8	152	121	40	,,
108	83·1	9·6	15·28	13·6	168	..	..	Temperature fluctuating.

TABLE D.—DATA FOR CURING EXPERIMENT D, STARTED 17TH MARCH, 1944

Hours in Kiln.	Loss in Weight.	Moisture in Sample.	Dry Matter.	Loss of Dry Matter.	Temperature in Kiln.		Relative Humidity.	Remarks.
					Dry Bulb.	Wet Bulb.		
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	° F.	° F.	Per Cent.	
0	..	80·6	19·35	..	..	..	..	..
6	2·6	..	..	..	84	83	96	Temperature rising.
12	6·4	..	..	..	82	82	100	Temperature slowly fluctuating.
18	4·9	82·2	16·90	12·7	85	82	87	Ditto.
24	6·1	81·5	17·41	10·0	85	83	91	,,
30	4·0	82·6	16·73	13·5	83	80	87	,,
36	8·7	80·8	17·52	9·5	83	80	87	Temperature steady.
48	13·3	80·6	16·77	13·6	90	85	80	Temperature rising slowly.
60	23·4	78·1	16·80	13·2	110	87	37	Ditto.
84	70·0	42·5	17·25	10·9	135	113	50	Temperature slowly fluctuating.
114	81·8	—1·2	17·03	12·0	170	..	..	Temperature steady.

TABLE E.—DATA FOR CURING EXPERIMENT E, STARTED 22ND MARCH, 1944

Hours in Kiln.	Loss in Weight.	Moisture in Sample.	Dry Matter.	Loss of Dry Matter.	Temperature in Kiln.		Relative Humidity.	Remarks.
					Dry Bulb.	Wet Bulb.		
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	° F.	° F.	Per Cent.	
0	..	80·9	19·06	..	..	..	..	..
6	4·5	80·8	18·37	3·6	80	78	91	..
12	12·6	79·5	17·95	5·7	80	75	78	..
18	15·9	78·3	18·28	3·7	84	82	91	..
24	22·2	75·9	18·75	1·6	85	83	91	..
30	27·3	76·1	17·35	8·8	87	83	84	..
36	26·7	77·3	16·68	12·5	85	80	79	..
48	36·7	73·6	16·71	12·3	87	83	84	..
60	66·3	52·4	16·03	15·9	110	100	70	..
84	82·9	4·9	16·29	14·5	160	100	13	..
108	84·0	3·3	15·50	18·7	170	..	..	..

NOTE.—No recorder chart available for this experiment.

(To be continued)

THE EFFECTS OF STEAM AND SOIL DISINFECTANTS ON THE YIELD AND QUALITY OF NELSON TOMATOES UNDER OUTSIDE CULTURE

By T. RIGG, E. B. KIDSON,* and E. T. CHITTENDEN, Cawthron Institute, Nelson, New Zealand

[*Received for publication, 18th September, 1941*]

Summary

Tests with steam, formalin, and bleaching-powder on a typical Nelson tomato soil under outside conditions of culture have been carried out.

Steam and formalin treatment effected a great improvement in growth of tomato-plants and resulted in an increase of 25 per cent. in yield. Steam treatment and, to a less extent, formalin treatment resulted in a very marked reduction in the amount of "hard-core."

Under the conditions of the experiment bleaching-powder was detrimental to growth of plants and yield of tomatoes.

STEAM sterilization of tomato-houses was introduced into Nelson some twenty years ago and has become an established annual practice of many tomato-growers. Very beneficial results on yield and freedom from disease have accompanied the steam sterilization of tomato-houses. In a recent test in a glasshouse of the Cawthron Institute the following yield results were obtained :—

Treatment.	Yield Tomatoes per Plant.
Steam sterilized	8 lb. 3 oz.
Not steamed	5 lb. 10 oz.

This result is fairly typical of the benefit which has been obtained by the steam sterilization of Nelson glasshouses. The beneficial effects of steam sterilization may be ascribed to the destruction of nematodes (particularly eelworm), the elimination of soil-borne diseases which attack the root-system of tomato-plants, and the release of available plant food. The part played by these different factors in Nelson tomato-houses is not known with certainty, but it seems probable that all the above-mentioned factors play an important role.

In view of the fact that many tomato-gardens in Nelson have been used for the culture of this crop for many years, it was thought possible that similar benefit might result from steam treatment or the use of soil disinfectants on garden soil under outside conditions of tomato culture. Accordingly, an experiment to test the value of steam treatment and the efficacy of formalin and bleaching-powder was arranged on the grounds of the Cawthron Institute where tomatoes have been grown for many years.

* Officer of Department of Scientific and Industrial Research seconded to the Cawthron Institute.

EXPERIMENTAL

Fifteen plots, each of which accommodated thirty plants, were arranged on a typical piece of tomato soil. Five plots were set aside as control plots; three were steamed to a depth of 14 in. using a steam grid at a pressure of 100 lb. to the square inch, four were treated with formalin at the rate of $\frac{1}{8}$ gallon of 40 per cent. formalin per square yard, and three were treated with bleaching-powder at the rate of 3 oz. per square yard.

Steam treatment was carried out on 1st October, 1943. The soil was rather too wet for the best results with steaming. The formalin and bleaching-powder were applied on 11th October. The formalin was diluted with 2 gallons of water and was used in two applications, half on the lower spit of soil and half on the top 4 in., which was temporarily removed to ensure the efficient treatment of the lower spit. In the case of the bleaching-powder the requisite amount for the plot was weighed out and thoroughly raked into the soil, which was then watered. After an interval trenches were drawn and a complete manure containing the following fertilizers was applied: superphosphate, 500 lb.; sulphate of potash, 200 lb.; ammonium sulphate, 90 lb.; and dried blood, 90 lb. per acre. A mixture of nitrogenous fertilizers consisting of nitrate of soda 80 lb. and dried blood 60 lb. per acre was applied as a top-dressing on all plots during the third week in December.

Tomatoes of the Potentate variety were planted on 21st October, 1943. Plants on the steamed and control plots were quick to establish and soon began to make satisfactory growth. The plants on the formalin-treated plots were adversely affected for a time, but very quickly recovered and later made strong, vigorous growth.

The plants on the plots treated with bleaching-powder were very badly affected by the use of this chemical and showed poor growth and yellowing of leaves for several weeks. Although later in the season improvement in growth occurred, the plants on the bleaching-powder plot were much poorer than those on the control plots. There can be little doubt that better results with bleaching-powder would have been obtained if the interval between actual treatment of the plots and the planting of the tomatoes had been greater. During the growing season the plants on the steam-sterilized plots showed a marked superiority over those on the control plots in regard to size of plant and freedom from disease. The formalin-treated plants, although backward in the early part of the season, made excellent growth later on and compared favourably with the plants grown on the steamed plots. The control plots gave very fair growth, but were not so vigorous as those under steam or formalin treatment and were more susceptible to disease.

YIELD OF TOMATOES

Harvesting of tomatoes commenced early in January, the fruit on the control and bleaching-powder plots being rather more forward than that on the steamed and formalin-treated plots. By the end of January the control and steam plots had averaged 2·3 lb., bleaching-powder 2·0 lb., and formalin 1·9 lb. per plant. During February the plants under steam and formalin treatments did exceptionally well and easily surpassed the yield from the control plots. The plants on the bleaching-powder plots showed a rapid decline in yield, the crop being considerably smaller than that from the control plots.

The results for the season, including green fruit left on the plants on 24th March, are shown in the following Table I.

TABLE I.—INFLUENCE OF STEAM AND SOIL DISINFECTANTS ON YIELD OF TOMATOES

Treatment	Pounds per Plant.
Control (five plots)	6·0; 6·5; 6·6; 6·1; 6·5—average, 6·3.
Bleaching-powder (three plots)	4·3; 4·2; 5·7—average, 4·7.
Formalin (four plots)	7·3; 7·5; 8·7; 7·9—average, 7·8.
Steam (three plots)	8·1; 7·3; 8·1—average, 7·8*.

* This figure is confirmed by the result from an adjoining experiment, where three plots with similar treatment likewise gave an average yield of 7·8 lb. per plant.

In comparison with the yield from the control plots of 6·3 lb. per plant, all treatments showed significant differences. The effect of the bleaching-powder was definitely detrimental, but the yields from the steamed and formalin-treated plots showed an increase of nearly 25 per cent.

QUALITY OF TOMATOES

A common defect of outside tomatoes in Nelson is that known locally as "hard-core." This term is applied to a hard pithy condition of the flesh of the tomato—more especially at the stalk end—which fails to ripen and greatly reduces the value of the tomatoes for both culinary and canning purposes.

One of the interesting results emerging from the treatments was the beneficial effect of both steam and formalin treatments on the incidence of this disorder. The following Table II shows the percentage of "hard-core" which occurred on the control, steamed, and formalin treated plots.

TABLE II.—INFLUENCE OF STEAM AND FORMALIN TREATMENTS ON INCIDENCE OF "HARD CORE"

Treatment.	Percentage of "Hard-core."		
	Healthy.	Slight.	Commercial.
Steam (average three plots)	61·7	28·9	9·4
Formalin (average four plots)	30·2	43·5	26·3
Control (average five plots)	16·9	34·9	48·2

The results show that steam treatment effected a reduction in commercial "hard-core" from 48·2 per cent. in the controls to 9·4 per cent. with steam treatment.

The formalin treatment likewise exerted a beneficial effect, which was more pronounced with the lower bunches of tomatoes than with those picked later in the season.

DISCUSSION

The effect of steam and formalin treatments in bringing about an improvement in both yield and quality of tomatoes is an outstanding feature of this experiment. The results suggest that many Nelson outdoor tomato-gardens will show a corresponding benefit from soil sterilization by these methods. Correlated with increase in growth of the plant above ground is a better development of the root system in the steam and formalin-treated

plots. An examination carried out at the end of the season revealed that whereas the roots of plants which had received these two treatments showed an excellent system of both principal and fibre roots of good colour, with little damage from disease or eelworm attack, those of the control plots were poor in development and colour, with extensive decay of the root fibres. The bleaching-powder plots resembled the controls in having a relatively poor root system, though in this case there were signs of injury which may have been chemical in origin.

No explanation has so far been found for the action of steam sterilization and, to a less extent, formalin treatment in decreasing the amount of "hard-core." It seems probable that one or both of the following factors may operate in this direction : (*a*) an increase in the availability of plant foods may be brought about by the soil treatment, (*b*) the reduction effected by sterilization in nematodes and soil-borne diseases may induce the development of a better root-system and therefore a better intake of essential plant constituents.

These questions will be considered in greater detail in a later paper in which the chemical analyses of leaves and fruit from the different plots will be presented.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the assistance rendered by Dr. K. M. Curtis on disease problems, and by Dr. M. Mayer in recording yields of tomatoes.

SOIL DISINFECTION

I. PRELIMINARY REPORT ON CONTROL OF EELWORM

By H. JACKS, Plant Pathologist, Plant Diseases Division, Plant Research Bureau, Department of Scientific and Industrial Research

[*Received for publication, 22nd September, 1944*]

Summary

1. Cresylic acid, naphthalene, formalin, calcium chlor-acetate, carbon disulphide, chloropicrin, D-D, and silver proteinite were tested for efficacy as soil disinfectants.

2. Chloropicrin gave good control of nematodes, and formalin delayed their activity sufficiently to allow good plant growth.

3. Carbon disulphide gave poor control of nematodes ; D-D and cresylic acid, although controlling eelworm, caused root injury and call for further investigation.

INTRODUCTION

DISINFECTION is important to the horticulturalist when it becomes necessary to destroy parasitic organisms in the soil. Steam is commonly employed as it is not only the most effectual agent known, but is of added value in that it kills weed-seeds and increases soil fertility. Equipment required is often too costly for owners of small glasshouses. Consequently an alternative

method is required that is both cheap and as effectual as steam. Various chemical soil treatments have been reported for control of eelworm (*Heterodera marioni* (Cornu) Goodey). Several were tested, in the work described below, with a view to selecting the most promising for further intensive investigation.

Chemical treatments for control of soil fungi form the subject of a later paper. Soil disinfectants, to be of practical value, should be equally effectual in combating both soil insects and fungi.

EXPERIMENTAL METHOD

Soil that had previously grown plants heavily infested with eelworm was used. It was mixed with sand and compost before treatment, to give the equivalent of normal potting soil. Treated soil was placed in glasshouse boxes (18 in. by 12 in. by 5 in.) and tomato-plants were grown as indicators of eelworm infestation. Records were taken of germination, vigour of growth, and degree of root infestation, and each test was carried out in duplicate or triplicate.

Formalin (40 per cent. formaldehyde) was diluted with water and applied at the rate of ½ gallon per box. The soil was then left for at least fourteen days before planting.

Cresylic acid, crude commercial grade, was mixed with water and applied at the rate of ½ gallon per box. A period of twenty-one days was allowed before planting.

Crude naphthalene, an unrefined product containing 76 per cent. naphthalene, 6·5 per cent. oils, and 1·1 per cent. phenolic bodies, was worked directly into the soil approximately fourteen days before planting.

Carbon disulphide, commercially pure, was injected by means of a burette into dibbled holes. Boxes were covered with wet sacks and the joints were sealed with tarred paper.

Calcium chlor-acetate (supplied by Imperial Chemical Industries, Australia, Ltd.), commercial grade, was worked directly into the soil.

Chloropicrin (supplied by Innis, Speiden, and Co., New York), commercially pure, was injected with a burette in holes 5 in. to 6 in. deep. The soil was held in metal containers or in boxes which were sealed with tarred paper. The treated soil was exposed after forty-eight to seventy-two hours' fumigation and left for approximately fourteen days before planting.

D-D (supplied by Shell Chemical Co., California), a by-product of petroleum, containing 96 per cent. of dichloropropane and dichloropropylene in equal parts in a 4 per cent. oil emulsifier, was first reported as a soil disinfectant by Carter (1943). It was applied in a similar manner to chloropicrin.

A solution of silver proteinite, first recommended by Hovy (1939), was applied in water to the test boxes.

In addition to treatment of soil in boxes, trials were carried out in a small glasshouse containing eelworm-infested soil. The available area was divided into plots of 12 square feet each, which were boarded to a depth of 10 in. Methods of treatment were essentially the same as those given above except that injections of chloropicrin and carbon disulphide were spaced at 1 ft. intervals. No provision was made for covering the soil, but the surface was sealed with water to a depth of approximately 1 in.

EXPERIMENTS WITH SOIL IN BOXES

TABLE I.—SHOWING PERCENTAGE GERMINATION AND INFECTION OF TOMATO SEEDLINGS IN VARIOUS SOIL TREATMENTS

Treatment.	Dosage per Box.	Mean Percentage Germination.	Mean Percentage Infection.*	
Experiment 1				
Check	..	60·0	96·7	
Cresylic acid..	56 ml. in 2,273 ml. water	43·0	61·0	
Naphthalene	15·7 g.	53·0	98·0	
Formalin	46 ml. in 2,273 ml. water	80·5	98·6	
Calcium chlor-acetate ..	3·0 g.	76·5	98·6	
Carbon disulphide	2·1 ml.	57·0	100·0	
Experiment 2				
Check	..	84·5	100·0	
Chloropicrin (treated in boxes)	4·0 ml.	93·0	15·6	
Chloropicrin (treated in tins) ..	4·0 ml.	91·0	0·0	
Chloropicrin (treated in drums)	4·0 ml.	94·5	4·6	
Experiment 3				
Check	..	86·5	100·0	
Steam sterilized soil	..	80·0	0·0	
Chloropicrin	3·0 ml.	96·0	17·8	
,, ...	6·0 ml.	89·0	4·5	
Experiment 4			Medium.	Severe.
Check	..	59·0	..	100·0
Calcium chlor-acetate.. ..	3·5 g.	72·5	82·7	17·3
,, ...	7·0 g.	85·0	80·6	19·4
,, ...	14·0 g.	65·0	81·4	18·6
,, ...	28·0 g.	25·0	100·0	0·0
Carbon disulphide	4·0 ml.	70·0	100·0	0·0
,, ...	8·0 ml.	55·0	13·5	86·5
,, ...	16·0 ml.	57·5	78·3	21·7
,, ...	32·0 ml.	72·5	100·0	0·0
Experiment 5		Percentage Survival.		
Check	..	79·5	0·0	100·0
Formalin	46 ml. in 2,273 ml. water	95·5	54·5	41·5
,, ...	29 ml. in 2,273 ml. water	100·0	17·5	82·5
D-D	2·0 ml.	94·5	0·0	0·0
,, ...	4·0 ml.	95·0	0·0	0·0
,, ...	8·0 ml.	95·0	0·0	0·0
Chloropicrin	2·0 ml.	100·0	73·6	4·4
,, ...	4·0 ml.	96·5	53·2	4·3
Experiment 6				
Check	..	97·5	97·0	
Chloropicrin	4·0 ml.	100·0	7·5	
,, ...	8·0 ml.	100·0	12·6	
Silver proteinite	0·18 g. in 500 ml. water	100·0	100·0	
,, ...	0·36 g. in 500 ml. water	95·0	95·0	
,, ...	0·72 g. in 500 ml. water	97·0	95·0	
,, ...	0·144 g. in 500 ml. water	95·0	94·5	

* Mean percentage infection of growing plants. In experiments 4 and 5 plants were graded into medium and severe, according to degree of gall development.

† Boxes were covered with tarred paper, tins sealed gastight, and drums covered with paper but not sealed.

Cresylic acid, naphthalene, and calcium chlor-acetate at high dosages caused injury at germination and stunting of plant-growth. Carbon disulphide and silver proteinite gave poor control of eelworm even at high dosages. Formalin did not prevent infection, but caused a delay in the attack of eelworm, which led to improved development of plants. D-D gave a high degree of control, but caused a marked reduction in the rate of plant-growth. Chloropicrin gave good control of nematodes and improved the vigour of plants.

EXPERIMENTS WITH GLASSHOUSE SOIL

TABLE II.—SHOWING PERCENTAGE INFECTION OF TOMATO-PLANTS GROWN IN VARIOUS TREATMENTS OF GLASSHOUSE SOIL

Treatment.	Dosage per Plot.	Percentage Infection.	
Experiment 7			
Check	..	100·0	
Naphthalene	151 g.	100·0	
Calcium chlor-acetate	28 g.	100·0	
Formalin	613 ml. in 6 gal. 5 pt. water	100·0	
Cresylic acid	726 ml. in 6 gal. ½ pt. water	14·3	
Carbon disulphide	20 ml.	100·0	
		Slight.	Heavy.
Experiment 8			
Check	..	22·0	78·0
Chloropicrin	24 ml.	31·0	0·0
Experiment 9			
Check	..	0·0	100·0
Chloropicrin	24 ml.	100·0	0·0

Cresylic acid gave control of eelworm, but caused severe damage to seedling plants and reduced vigour of growth. Chloropicrin reduced the degree of eelworm infestation. Plants grown during winter months (experiment 8) showed vigorous growth in treated plots, weight of green-tops being four times that of the checks. Plants grown during summer months (experiment 9) showed severe eelworm infestation in check plots, but there was no reduction in rate of growth.

CONCLUSION

Of the treatments investigated, chloropicrin, D-D, and formalin appear worthy of further investigation. Silver proteinite, calcium chlor-acetate, and naphthalene did not give effective control of nematodes.

Carbon disulphide requires further testing, but is unlikely to be of practical value. Before rejecting cresylic acid further investigation in relation to plant damage is necessary.

REFERENCES

CARTER, W. (1943): A Promising New Soil Amendment and Disinfectant. *Science*, *97*, 383–4.

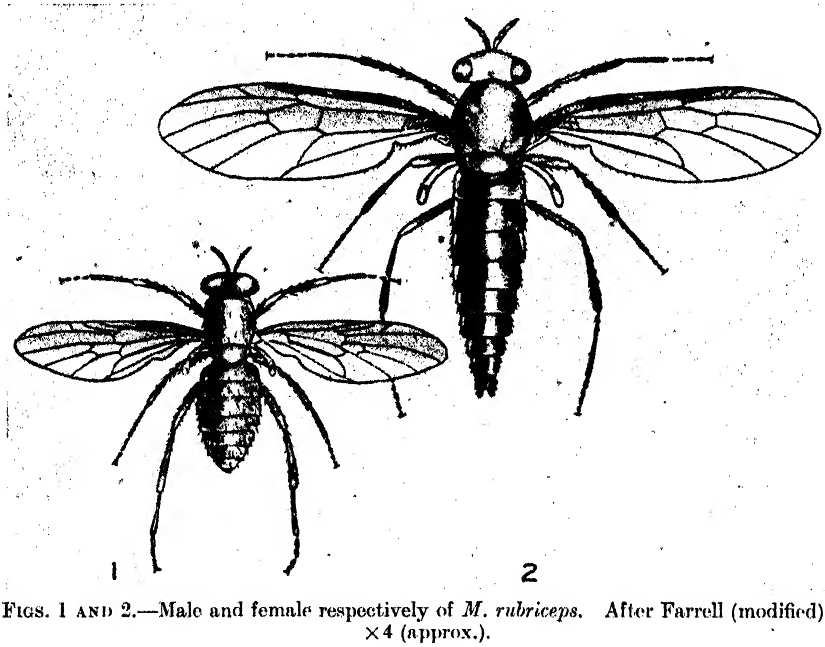
HOVY, J. W. H. (1939): Oligodynamic Control of Eelworm (*Heterodera marioni*). *Nature*, *144*, 672.

RECORD OF AN AUSTRALIAN FLY (*METOPONIA RUBRICEPS*, MACQUART) FOUND IN PASTURES IN OPOTIKI

By J. MUGGERIDGE, Entomology Division, Plant Research Bureau, Department of Scientific and Industrial Research

[*Received for publication, 21st August, 1944*]

MR. J. R. Murray, Instructor in Agriculture, found from discussions with farmers, and from his own observations in the Opotiki district, to use his own words, "that it was becoming increasingly difficult to keep even the best of the rye-grass strains for more than the second season." Followed a close examination of the pastures, with the result an insect in the larval stage was found to be very prevalent in the ground about the roots of grasses, and this insect, it was thought, was the cause of the pasture deterioration.



FIGS. 1 AND 2.—Male and female respectively of *M. rubriceps*. After Farrell (modified). ×4 (approx.).

Specimens of the larvæ were sent to the Division for identification. The larvæ were reared to the adult stage and identified by Dr. D. Miller as *Metoponia rubriceps*, Macq. It is regarded as an Australian species, and identification was subsequently confirmed by Australian authorities. *M. rubriceps* belongs to the family Stratiomyiidæ and sub-family Beridinæ. Hardy(1), in his key to genera Australian Beridinæ, points out that in the genus *Metoponia* Macquart the scutellum is without spines and the wings have three posterior veins; and the species *rubriceps* has "the first joint of the antennæ conspicuously longer than the second; a black, brown, or reddish species, and the female with a reddish head." The length of the male fly is 5–6 mm., and the female 6–10 mm. (Figs. 1 and 2 respectively).

The larva (Fig. 3), which is approximately 10 mm. in length when full grown, is a very soiled whitish colour, or perhaps soil coloured, though it does not blend completely with its environment. Irwin-Smith(2), who has made detailed morphological studies of different stages of this insect, points out that the young larval stage is dorso-ventrally flattened: she stated: "In transverse section the segments have the shape of a bi-convex lens, with the lateral edges expanded into tumid ridges, marked off from the main body, on both surfaces, by a shallow groove." The same author points out that the larva obtains its food by sucking the juices from the roots of grasses. The mouth parts are said to feature very well the parallel jaws, which work upwards, outwards, and downwards, features characterizing a group of fly larvæ, including the Stratiomyiidæ.

3

[*Photo by Given.*

FIG. 3.—Larvæ of *M. rubriceps*. ×6 (approx.).

The life-history is imperfectly understood, and Irwin-Smith (*l.c.*) states "it is already clear that, although two broods of flies appear annually, the larval period requires more than six months for its completion, and very probable that it requires considerably longer than twelve months."

The writer visited the locality at Opotiki where *M. rubriceps* was prevalent and found from a brief examination that, wherever the pasture was seriously depleted, large numbers of the above insects could generally be found. Upon close investigation it was common to find them in great numbers about the roots of grass within 2 in. or 3 in. of the ground surface. They were found not only about the roots of rye-grass, but also about the roots of maize and lupin. Irwin-Smith (*l.c.*) in Australia found fully grown larvæ wedged

in between rhizomes of paspalum grass. The farmers of the district have pointed out that attacks on maize are usually serious in the first year's planting, but are much reduced in the second year—*i.e.*, after ploughing from lea and planting maize the results are very poor, but if the same paddock is planted again the following year a good crop can usually be relied upon. They point out also that paddocks sown in rye are apparently not seriously affected at first, but, later on—that is, in a year or two—they are seriously attacked, with the result that the pasture becomes completely ruined.

ACKNOWLEDGMENTS

I wish to thank Dr. D. Miller for the identification of the insect and references, and Mr. B. B. Given for preparation of the illustrations.

REFERENCES

(1) HARDY, G. H.: Australian Stratiomyiidæ. Royal Society of Tasmania: Papers and Proceedings, 1920, 33–64.
(2) IRWIN-SMITH, VERA: Studies in Life-histories of Australian Diptera Brachycera. *Proc. Linn. Soc., N.S.W.* (1920) *XLV*, 505–530; (1921) *XLVI*, 252–255 and 425–432; (1923) *XLVIII*, 49–81 and 368–374.

LONGEVITY OF DIAMOND-BACK MOTH (*PLUTELLA MACULIPENNIS*) ADULTS IN RELATION TO NUTRITION

By B. B. GIVEN, Entomology Division, Plant Research Bureau, Nelson

[*Received for publication, 25th July, 1944*]

INTRODUCTION

THE following experiments were conducted during an investigation of the overwintering of diamond-back moth in New Zealand. It was decided that the relative merits of two different feeding solutions should be tested at the same time, as a guide to feeding technique for laboratory breeding. The usual feeding solution used in Nelson for parasite and host colonies has for several years been a mixture of honey and pollen comb ("bee bread") mashed in water and filtered. This solution has been found excellent for use in breeding Hymenoptera, and has produced a high percentage of female progeny in all species handled. Its effect on longevity and fertility of lepidopterous host material was determined in comparison with the effects of feeding on honey in the following experiments.

TECHNIQUE

Moths were confined in glass tubes 6 in. long and 1¼ in. in diameter (Fig. 1). Each tube was closed at one end with muslin, and at the other end with a cork through which projected a glass tube containing the nutrient solution. These feeding-tubes were sealed at the outer end, and closed at the inner end with absorbent cotton-wool. Each tube contained 20 freshly-emerged moths, and feeding solutions where moths were fed continuously were renewed every second day.

LONGEVITY EXPERIMENTS

These experiments were conducted in an insectary with free circulation of air through gauze sides and without heating-appliances. Experiments commenced on 2nd July, 1938, and terminated on 20th October, 1938.

The temperature ranged from a maximum of 77° F. to a minimum of 27° F., with a mean of 49° F., which is from 1° F. to 2° F. above the normal outside mean for the same period.

The following treatments were used :—

A. Fed one day—
  (*a*) Honey solution.
  (*b*) Honey and pollen solution.
  (*c*) Water.

B. Fed continuously—
  (*a*), (*b*), (*c*), as above.

C. Controls—
  No food.

Four complete sets of the above treatments were set up. In each set all treatments were commenced simultaneously and the four sets overlapped. Results were combined to produce the graph (Fig. 2). This means that 80 moths were treated under each of the above feeding conditions, or a total of 560 moths was handled in all. In analysis of figures, results for males and females were at first considered separately, but as no difference in mortality-rate could be detected they were finally considered together.

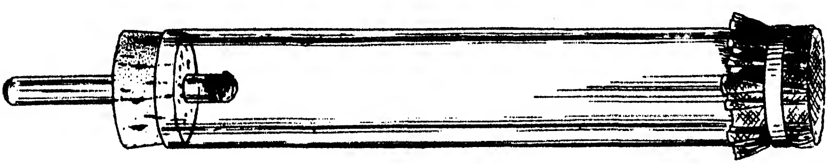


FIG 1.—Tube used in feeding experiments.

The difference in results requires no comment. Continuous feeding on honey solution is obviously the most satisfactory, while continuous feeding on honey and pollen is also fairly good. However, this graph does not take into account the oviposition rate or the effect on fertility of the different solutions.

EFFECT OF FOOD ON FERTILIZATION AND OVIPOSITION

Two tubes were set up as in the previous set of experiments, and the moths in one were fed continuously on honey and pollen, and in the other on honey solution. Each tube contained 10 male and 10 female moths.

Tubes were placed in a heated glasshouse, shaded from any direct heat, at a minimum temperature of 63° F. The maximum temperature was in the vicinity of 90° F. Feeding solutions were changed every second day, and egg and larval counts taken twice per week.

TABLE I.—OVIPOSITION AND FERTILITY OF PLUTELLA

Feeding Solution.	Total Eggs.	Total Hatch.	Approximate Percentage Hatch.
Honey	131	92	70·3
Honey and pollen	119	104	87·3

The above table indicates that the fertility of females where both sexes are fed on honey and pollen is higher than when fed on honey. However, this is only an indication, and in both cases the fertility is high.

CONCLUSION

The above experiments clearly indicate the ability of *Plutella* adults to survive prolonged periods of adverse conditions. The necessity for an adequate supply of suitable food is apparent, and food stored in the body as a result of feeding for a short period appears to be negligible, since feeding for one day prolongs life only very slightly more than when not fed at all. Fertility appears to be fairly high with either of the foods compared.

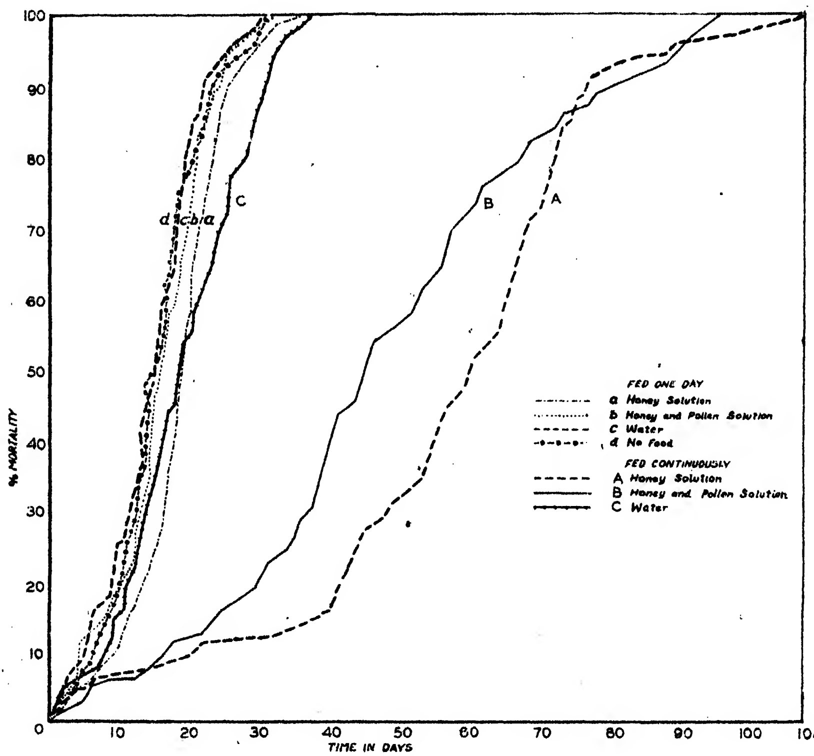


FIG. 2—Graph illustrating mortality of diamond-back moth adults under different feeding conditions.

REFERENCES

HARDY, J. E. (1938): *Plutella maculipennis*, Curt.; Its Natural and Biological Control in England. *Bull. Ent. Res.*, *29*, 4.

ROBERTSON, P. L. (1939): Diamond-back Moth Investigation in New Zealand. *N.Z. J. Sci. & Tech.*, *20*, 5A and 6A.

WELLMER, W. (1937): "Beitrag Zur Kenntnis der Kohlschabe *Plutella maculipennis*, Curtis." Bonn University Press.

THE RELATIVE FOOD-CONSUMPTION OF DIAMOND-BACK MOTH AND WHITE BUTTERFLY LARVÆ

By B. B. GIVEN, Entomology Division, Plant Research Bureau, Nelson

[*Received for publication, 25th July, 1944*]

Summary

The volume of cabbage-leaf consumed by larvæ of *Pieris* and *Plutella*, has been measured and compared as both a daily and total quantity, and the velocity of food-intakes graphed comparatively for the two insects. It has been pointed out that the true relative-damage index of equal populations, will be in the ratio of the daily food-intake over the entire life-cycle from oviposition to oviposition of the progeny, and this index has been worked out.

IN order to compare populations of white butterfly (*Pieris rapae*) and diamond-back moth (*Plutella maculipennis*) in relation to damage, it is important to know the relative amount of food consumed by larvæ of each species, and also the differences in the duration of the feeding period and the proportion of the entire life-cycle during which active feeding takes place. In the following account, this comparison is made.

TECHNIQUE

Individual larvæ were caged over portions of cabbage-leaf on potted plants in a thermostatically-controlled insectary. The type of cell used is

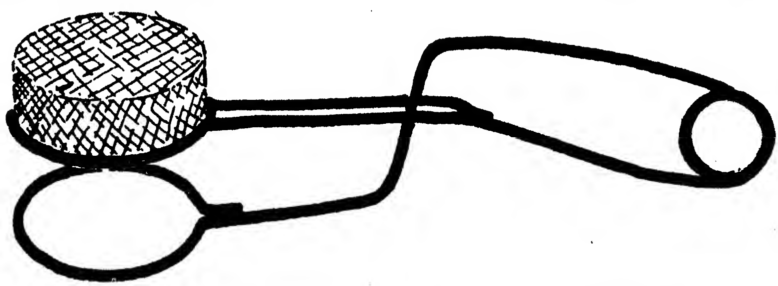


FIG. 1.—Spring-clip cell used to confine larvæ on cabbage-leaves.

illustrated in Fig. 1. It is in the form of a wire clip to which is attached a wire gauze chamber approximately 1 in. in diameter. These cells were moved to fresh portions of leaf each day, and the areas of leaf eaten were measured under a celluloid slide divided into 0·0025 square centimetre divisions. The volume of leaf eaten was calculated from areas measured, and leaf thickness, measured daily on fresh sections, under a calibrated eye-piece micrometer. Twelve larvæ of each species were used, but, of these, only six of *Pieris* and ten of *Plutella* survived.

RESULTS

The following table gives the figures resultant on the writer's experiments:—

TABLE I.—RELATIVE FOOD INTAKE OF PLUTELLA AND PIERIS LARVÆ

Species.	Number of Larvæ.	Mean Temperature.	Mean Volume of Leaf, in Cubic Centimeters.	Mean Length of Feeding Period.
		°C.		
Pieris rapae ..	6	22	0·7144 ± 0·0151	14·5
Plutella maculipennis	10	22	0·0556 ± 0·00245	10·5

The mean length of feeding period should be approximately the same as the length of larval life as determined at constant temperatures, and in this respect we may use the results of various authors as a check. Muggeridge (1942) has worked out the thermal constant and threshold of development for *Pieris rapae* in New Zealand, and from his figures, using the formula $(T - K)D = C$, where T = temperature °C., K = threshold of development, D = duration in days, and C = thermal constant, the theoretical duration of the larval stage at 22° C. is 13·6 days, which is in close agreement with the author's result (14·5 days).

From the figures obtained by Hardy (1939), Wellmer (1937), and Kanervo (1936), the duration of the larval life of *Plutella maculipennis* at 22° C. should be about 10 days, which is also in close agreement with the observed

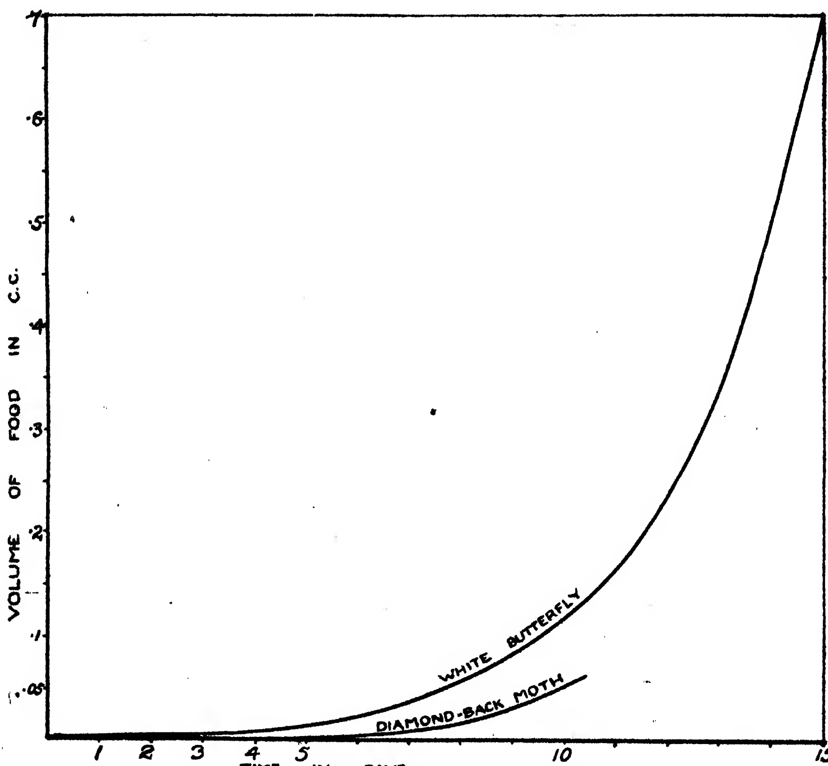


FIG. 2.—Graph illustrating relative food-consumption and length of larval life of *Pieris* and *Plutella* larvæ at 22° C.

results of the writer (10·5 days). The above comparison of results is of interest as a check by actual observation on results obtained partially by calculation.

Figure 2 illustrates graphically the relative food-consumption of *Pieris* and *Plutella* larvæ and also the relative duration of time of feeding. It will be noted that during an equal period of time, from emergence to the end of feeding-time for *Plutella*, the ratio of food-consumption of *Pieris* to *Plutella* is approximately 2·4 : 1, whereas to the end of feeding of each it is approximately 14·5 : 1.

In considering the relationship between populations of the two insects, however, we must consider the entire period from oviposition to maximum oviposition of resulting adult progeny. In the present discussion it is assumed that the total amount of food consumed by each species is constant, irrespective of temperature, at least within reasonable limits. Insufficient information is available regarding the pre-oviposition period of the two species, but it seems probable that in both cases this period at favourable temperatures will be in the vicinity of 4 or 5 days after emergence. In any case, the period prior to maximum oviposition under favourable conditions is not protracted, as is the case with so many insects. For the purpose of this article we will assume this period to be 4 days in the case of each insect at 20° C.

Then from the figures of Muggeridge (1942) for *Pieris*, and Hardy (1939), Wellmer (1937), and Kanervo (1936), for *Plutella*, we can illustrate approximate life-cycles as in Fig. 3. It will be seen that at 20° C., although the

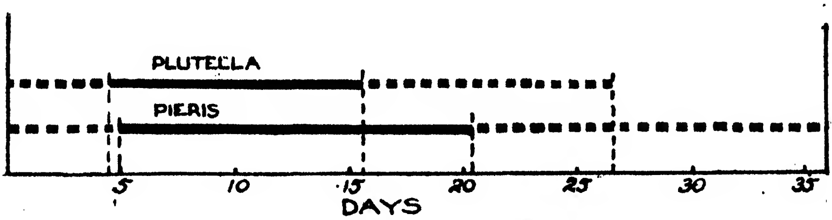


FIG. 3.—Duration of single generation of *Pieris* and *Plutella* at 20° C. The solid line represents the larval stage.

entire cycle occupies 26·5 days for *Plutella* and 36 days for *Pieris*, the feeding (larval) periods are only 11 and 15·5 days respectively. Thus, the actual food-consumption per day of a complete generation of one specimen of each species would be approximately 0·0021 cubic centimetres for *Plutella* and 0·0198 cubic centimetres for *Pieris*. Under normal conditions, then, the true relative-damage index for a single generation succession would be—

$$\frac{\textit{Pieris}}{\textit{Plutella}} = \frac{198}{21} = 9{\cdot}4 : 1.$$

REFERENCES

HARDY, J. E. (1939): *Plutella maculipennis* Curt.; Its Natural and Biological Control in England. *Bull. Ent. Res.*, *29*, 4.

KANERVO, V. (1936): The Diamond-back Moth (*Plutella maculipennis* Curt.) as a Pest of Cruciferous Plants in Finland. *Agr. Expt. Activities of the State*, No. 86, Helsinki.

MUGGERIDGE, J. (1942): The White Butterfly (*Pieris rapae* L.): Its Establishment, Spread, and Control in New Zealand. *N.Z. J. Sci. & Tech.*, *24*, No. 3A.

WELLMER, W. (1937): "Bietrag zur Kenntnis der Kohlschabe *Plutella maculipennis* (Curtis)." Bonn, University Press.

NOTES ON THE PHYSICAL ECOLOGY OF *DIADROMUS* (*THYRAEELLA*) *COLLARIS*, GRAV.

By B. B. GIVEN, Entomology Division, Plant Research Bureau, Nelson

[*Received for publication, 25th July, 1944*]

INTRODUCTION

Diadromus collaris was introduced into New Zealand as a pupal parasite of the diamond-back moth (*Plutella maculipennis*). The material was consigned in the larval or pupal stages in host pupæ, and during transit was stored in vegetable cool chambers on board ship at a temperature of approximately 45° F. Of material sent, only about 1 per cent. survived. This low survival led to basic experimental work being conducted regarding temperature reactions of the insect, with a view to improvement in methods of transport. Later this work was extended to give some indication of the reactions of the insect to its climatic environment. The present paper deals with the more fundamental aspects of these experiments.

TEMPERATURE REACTIONS

From the exceedingly high mortality-rate in consignments, it was assumed that exposure to low temperatures would prove to be a primary factor in limiting the climatic range of the insect in New Zealand. Consequently, parasitized material was placed in cool store at constant temperatures and mortality-rate noted.

In the first experiment, six tubes, each 6 in. by 1¼ in., covered at each end with muslin, and each containing twenty parasitized pupæ, were placed in cool store at 4·5° C. Two tubes were removed each fortnight, placed in an incubator at 18° C., and emergence recorded. Results were as follows :—

TABLE I.—COLD-HARDINESS OF PRE-ADULT DIADROMUS COLLARIS

Tube No.	Number of Parasitized Pupæ	Days at 4·5° C.	Parasites emerging.	Percentage Mortality.	
1	20	14	5	75	50
2	20	14	15	25	
3	20	28	1	95	90
4	20	28	3	85	
5	20	42	0	100	100
6	20	42	0	100	

A further set of six tubes each containing twenty parasitized pupæ was placed in cool store at 7·2° C. and left for emergence. No material emerged, and after sixty days all material was dissected and found to be dead.

The above results, then, indicated a high zero of development and a low resistance to prolonged cold in the pre-adult stages. The fact that all material dissected was in the pre-pupal stage indicates this stage as being the critical one. Following on these experiments, trial packages of adult insects were made up and tested for mortality under postal conditions. A series of six tubes, each containing one hundred parasites, was prepared and

wrapped as for postage. Each tube was 6 in. by $1\frac{1}{4}$ in., covered at each end with muslin, and with a pad of cotton-wool dipped in honey solution pinned to one muslin cover. Four tubes were placed in the laboratory exposed to normal fluctuations of temperature, while the remaining two were placed in cool store at 7·2° C. After a period of three days the condition of all material was very good, the highest mortality-rate being in the tubes in cool store (20 per cent., approximately). However, after forty-two days the mortality of this material in cool store had risen only to 60 per cent., all survivors being females.

From this experiment it was determined that the transport problem could be countered by sending adult instead of pre-adult stages.

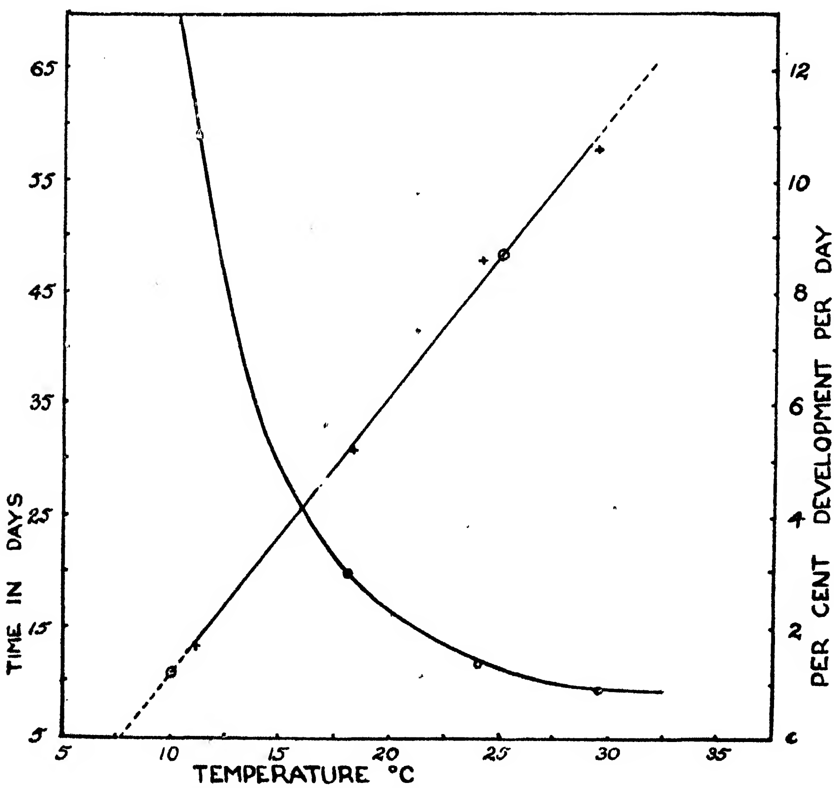


FIG. 1.—Developmental hyperbola and velocity of development curve for *Diadromus collaris* from oviposition to emergence at 70 per cent. R.H.

Following on the above results, the velocity of development curve for pre-adult stages in relation to temperature was worked out. Humidity was kept constant at 70 per cent. R.H. by suspending material in tubes open at each end, over sulphuric acid of S.G. 1·250, in pound screw-top preserving-jars. Temperatures from 18° C. to 48° C. were maintained with a range of ± 1° C, in electrically-heated incubators, and lower temperatures were controlled in a cool store with a range of approximately ± 0·5° C. All fundamental data recorded are in the following table. Parasitized pupæ were placed in humidity jars within thirty minutes of oviposition.

TABLE II.—PRE-ADULT DEVELOPMENT PERIOD

Mean Temperature.	Number of Insects used.	Number of Insects maturing.	Mean Developmental Period, in Days.	Percentage Mortality.
°C.				
4·5	60	0	..	100
11	102	28	59·15	72·5
18	94	23	19·8	25
24	128	29	11·7	15·2
29·5	122	116	9·3	4
32·9	70	0	..	100
35	106	0	..	100
48	46	0	..	100

From the above results the velocity of development curve (percentage development per day) has been constructed (Fig. 1), the straight line being fitted to the data by the method of least squares. The upper limit must

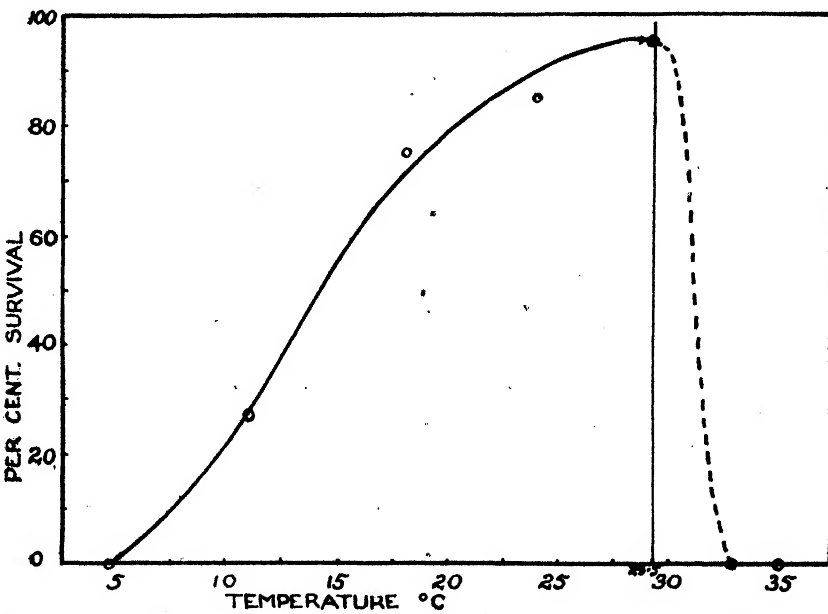


FIG. 2.—Percentage survival curve at constant temperatures and 70 per cent. R.H. for *Diadromus collaris* pre-adult stages.

be approximately 30° C., but is remarkably close to the approximate optimum at 29·5 according to mortality figures.

The remarkable rise in mortality (Fig. 2) above 29·5 was checked by use of various humidities, but in all cases results were the same.

The calculated zero of development and thermal constant are as follows :—

Zero of development = 7·6° C.

Thermal constant = 200·1 day degrees.

The above figure for the thermal constant cannot be used as a basis for calculating possible number of generations at any locality, as it does not take into account the adult period prior to maximum oviposition when mating, and, in the case of females, feeding on host pupæ, is in progress (Bodenheimer,

1938). According to Lloyd (1940), this period at 20° C. is approximately seven days, which would bring the thermal constant for the complete life-cycle to approximately 287 day degrees.

EFFECTS OF HUMIDITY

The effects of humidity on pre-adult stages are obviously indirect, acting through the host pupa. Since humidity has little effect on the development of *Plutella* pupæ, it does not materially affect *Diadromus*, at least within the limits of 30 per cent. R.H. to 90 per cent. R.H. Below 30 per cent. R.H. pupæ become dessicated, and above 90 per cent. R.H. they tend to develop bacterial infections and decay.

Various solutions were tried for humidity, as it was suggested that the vapour of the acid over sulphuric acid solutions may be detrimental. However, no visible differences could be detected in results using sulphuric acid, potassium hydroxide, and glycerine solutions.

REFERENCES

BODENHEIMER, F. S. (1938): "Problems of Animal Ecology." Oxford University Press.

BUXTON, P. A., and MELLANBY, K. (1934): The Measurement and Control of Humidity. *Bull. Ent. Res.*, *25*, 2.

DAVIDSON, J. (1942): On the Speed of Development of Insect Eggs at Constant Temperatures. *Austr. J. Expt. Biol. and Med. Sci.*, *20*, 4.

DUMBLETON, L. J. (1939): Contribution to the Physical Ecology of *Tortrix postvittana*, Walk. (Lep.). *Bull. Ent. Res.*, *30*, 3.

LLOYD, D. C. (1940): Host Selection by Hymenopterous Parasites of the Moth *Plutella maculipennis*, Curtis. *Proc. Roy. Soc. Lond.*, *Ser. B*, No. 853, Vol. 128.

SHELFORD, V. E. (1929): "Laboratory and Field Ecology." Boilliere, Tindall, and Co., London.

UVAROV, B. P. (1931): Insects and Climate. *Trans. Ent. Soc. Lond.*, LXXIX, Pt. 1.

THE ADDITION OF WHEY CREAM TO MILK USED FOR CHEESE-MANUFACTURE

By H. R. WHITEHEAD, Dairy Research Institute (N.Z.), Palmerston North

[*Received for publication, 7th August, 1944*]

Summary

War conditions made it necessary to investigate the possibility of the incorporation of recovered whey fat in cheese.

Whey cream, after treatment at 200° F. for thirty minutes to destroy bacteriophage, was added to cheese milk in proportions which gave fat additions of from 6 per cent. to 27 per cent. of the fat in the original milk. No difficulty was experienced in the manufacture of the cheese, nor was the quality any lower than that of control cheeses at any stage of maturity.

The extra cheese yielded by the added fat amounted to approximately 1·2 × weight of added fat.

INTRODUCTION

IN New Zealand all the whey drained from cheese-vats is passed through separators to remove as much of the butterfat as possible. The fat recovered amounts to between 5 per cent. and 7 per cent. of the total fat present in the cheese milk. In normal times the whey cream is churned into butter, which is either consumed locally or exported for use by pastrycooks.

At the beginning of the 1941–42 dairying season, owing to war conditions, it became doubtful whether refrigerated shipping space would be available for the export of New Zealand's output of whey butter. It therefore became necessary to consider alternative methods of profitable disposal. In the final event the whey butter was converted into dry butterfat, which could be shipped as ordinary cargo, but before the decision was made to take this course, another method, the return of whey cream to the cheese-vat, was tried out. Mr. J. Murray, secretary of the New Zealand Dairy Factory Managers' Association, who suggested the latter method, informed us that it had been used successfully many years ago. It was realized that this method of disposal of whey butterfat would give a lower monetary return than the normal method of converting it into whey butter because the butter is worth about 14d. per pound, while cheese is worth about 8¾d. per pound, but it was considered advisable at least to determine whether the whey fat could be incorporated in cheese successfully in case no more profitable method of disposal was feasible. The questions at issue were—

(1) Is cheese to which whey fat has been added equal in quality to normal cheese at all stages of maturity?

(2) What extra weight of cheese does a given weight of added whey fat produce?

TRIALS AT INSTITUTE EXPERIMENTAL FACTORY

Two series of trials were carried out in which cheese was made daily from 800 lb. of milk to which whey fat had been added; control cheese was made from similar milk with no addition of fat. All the cheese milk was flash-pasteurized at 155° F. according to normal New Zealand practice.

Throughout the experiments the fat content of the normal milk ranged between 4·1 per cent. and 5·5 per cent.

In the first series, extending over eight days, the proportion of whey fat added varied on different days from 6 per cent. to 27 per cent. of the fat in the normal milk. In the second series, extending over thirteen days, the fat recovered from the whey from the experimental vat each day was added to the experimental vat on the succeeding day. Thus the proportion of whey fat added was equivalent to that normally lost in the whey—viz., about 6 per cent. of the total fat in the milk in the cheese-vat.

TREATMENT OF THE WHEY CREAM

From previous work on cheese-manufacture at the Institute it was known that the main danger in adding whey cream to a cheese-vat lay in the presence of bacteriophage in the cream serum. The addition of the phage to the cheese-vat, especially where the same starter was in use from day to day, would inevitably cause a "dead" vat, due to destruction of the starter by phage during the course of cheese-manufacture. In these experiments, therefore, the whey cream, containing about 50 per cent. fat, was heat-treated before addition to the pasteurized milk in the vat. At first the treatment consisted in standing the cream-can in hot water and maintaining the cream at 170° F. for half an hour. (The highest thermal death point for any streptoccocal phage so far encountered is 167° C. for thirty minutes.) It was soon found, however, that the margin of safety in this treatment was too low for factory practice. On two or three occasions in preliminary work the starter failed completely in an experimental vat, while it behaved quite normally in a control vat. After various trials it was found that a safe procedure from all points of view was to

raise the cream to 200° F. by admission of live steam and to maintain this temperature for thirty minutes. Contrary to expectations, this treatment did not result in a breaking of the cream emulsion and consequent "oiling off" on the surface of the milk in the cheese-vat. The whey cream was added to the vat a few minutes before the rennet.

MANUFACTURE OF THE CHEESE

No difficulty whatever was experienced during the manufacturing process. There was no extra free fat to be observed on the surface of the milk or whey in the experimental vat as compared with the control vat. Acidity developed at the same rate in the two vats each day, and the only difference remarked upon by the cheesemaker was a slightly "weaker" body in the experimental curd in the later stages of the process than in the control curd, particularly where the larger whey-fat additions were concerned.

QUALITY OF THE CHEESE

Throughout the curing period at 55° F. up to six months (the last examination) there was no significant difference in quality between control and experimental cheeses. The only distinction was a slightly softer (more "buttery") body in the experimental cheeses into which the larger proportions of whey fat had been incorporated. None of the experimental cheeses showed "pockets" of free fat.

EXTRA CHEESE YIELD GAINED BY ADDITION OF WHEY FAT

In both series of experiments the milk, starter, and whey cream were accurately weighed into the vats and the composition of the milk and whey cream was determined. The cheese produced was also weighed. Thus it was possible, since the milk used in the control and experimental vats was identical in compostion, to assess the additional cheese produced for a given whey-fat addition.

In the first series, extending over eight days, a total of 50·7 lb. (fourteen-day weight) additional cheese was made in the experimental vats (assuming exactly the same yield for the original milk as in the control vats) for a whey-fat addition of 43·18 lb. Thus the extra cheese weight was 1·17 × whey fat added.

In the second series, extending over thirteen days, a total of 34·9 lb. extra cheese was made for a whey-fat addition of 28·8 lb. Thus the extra cheese weight was 1·21 × whey fat added.

In both series, therefore, the addition of whey fat resulted in an increased weight of cheese equal approximately to 1·2 × weight of fat added.

FURTHER TRIALS

Subsequent to the controlled experiments described above a series of trials without controls was carried out. The whole of the whey cream derived from the previous day's cheesemaking was added to the vats on more than a hundred days during the 1941–42 season in the experimental factory. Normal cheesemaking procedure was followed, and the only difficulty experienced was on the two or three occasions at the beginning of the trials when bacteriophage in the whey cream was not completely destroyed. After the adoption of the method of treatment of the cream with live steam there was no further trouble. Throughout the whole period there was no significant increase in the quantity of whey cream obtained from day to day, indicating that the added fat was being

incorporated in the cheese. Free fat was never noticeable in the vats, nor were "pockets" of fat observed in the cheese. All the cheese passed the grading examinations as normal cheese both at fourteen days and (with those retained for three months or more) at maturity.

A trial was also made in four vats in a commercial cheese-factory over a ten-day period. Here again no control vats could be used and the trial consisted merely in the addition to the milk in the vats of all the whey cream separated from the whey on the previous day. The cheeses both at fourteen days and after six months' storage in the cool store at the shipping port were considered by the graders of the Dairy Division to be quite normal good-quality cheese. There was nothing to suggest that the quality had suffered through the addition of the whey fat.

All the results indicated that it is possible, without prejudice to cheese quality, to add whey fat to cheese milk to the extent of at least 6 per cent. of the fat in the milk. The only point which needs constant attention is the efficiency of pasteurization of the whey cream before its addition to the milk. The heat treatment must be sufficient to destroy all traces of bacteriophage, otherwise starter failures during the course of manufacture are almost inevitable.

Acknowledgments are due to the following, who co-operated in the experiments described above: Messrs. C. Stevenson, J. Walker, and A. Drake, of the Dairy Division of the Department of Agriculture; Mr. L. Hunter, manager of Mangawhata Dairy Co.; Messrs. G. J. Hunter and E. Sawyer, of the Institute staff.

NEW ZEALAND CREAMERY COSTS AND PAY-OUTS FOR THE 1937-38 SEASON

By J. F. TASKER, Dairy Research Institute (N.Z.), Department of Scientific and Industrial Research, Palmerston North

[*Received for publication, 1st September, 1944*]

Summary

The 1937-38 working-costs and pay-outs of a group of forty-nine creameries in the Auckland and Wellington provinces are surveyed. It is shown that, as compared with the average small creamery, the total manufacturing costs per pound of butterfat of the average large creamery are low, and its pay-out per pound of butterfat is high.

SINCE January, 1937, all dairy companies in New Zealand have been required under the Dairy Industry Accounts Regulations to prepare their annual accounts in a standardized form and to supplement these accounts with certain statistics and information concerning their operations. This has given an opportunity, which does not exist to the same extent with other industries in New Zealand, to study as a whole the costs of the manufacturing side of the New Zealand dairy industry, and to investigate the factors affecting them.

The Export Division of the Marketing Department includes in its annual report averages of these costs by grading ports and for the whole Dominion. This paper seeks to supplement the averages given for buttermaking costs for the 1937-38 dairying season* by showing how these costs are related to the factory's volume of production, which, it will be seen, is the most important single factor affecting unit costs of buttermaking.

* *Vide* p. 38, annual report (second) of the Primary Products Marketing Department for the year ended 31st July, 1938.

NATURE AND TREATMENT OF THE DATA

The data which are summarized in this paper have been taken from the 1937–38 annual reports and manufacturing accounts of forty-nine dairy companies scattered throughout the Auckland and Wellington provinces. These companies produced approximately two-fifths of the total quantity of butter made in New Zealand during 1937–38, and a little over half the total butter-production of the Auckland and Wellington provinces for that season.

In the analysis the companies have been grouped by steps of 500 tons into seven production classes. All costs have been given in terms of pence per pound of butterfat.

The numbers of companies falling within each class, together with other relevant data, are given in Table I.

TABLE I

Production Class.	Number of Companies	Average Suppliers per Company.	Average Pounds Butterfat per Supplier.	Production.			Average Overrun.	Average Butter Grading.
				Average.	Highest.	Lowest.		
Tons.				Tons.	Tons.	Tons.	Per Cent.	Points.
Under 500	10	141	4,372	336	497	110	21·65	93·36
501–1,000	11	324	3,975	700	994	523	21·59	93·63
1,001–1,500	8	442	5,099	1,225	1,355	1,022	21·88	93·98
1,501–2,000	7	448	7,015	1,706	1,875	1,524	21·70	93·63
2,001–2,500	5	719	5,537	2,168	2,421	2,057	21·89	93·55
2,501–3,000	5	615	8,484	2,838	2,970	2,578	21·78	93·50
Over 3,000	3	734	10,044	4,007	4,832	3,308	21·80	93·33
Total	49							

As far as possible the results of subsidiary activities (such as trading with suppliers) have been eliminated from the data, and where a company had more than one factory it has been treated as a single unit. Because only three companies among those covered produced more than 3,000 tons of butter during the 1937–38 season, the curves in the graphs have not been extended beyond the 3,000-ton ordinate.

MANUFACTURING AND MARKETING COSTS

In Fig. 1 individual and average total costs per pound of butterfat are plotted, together with the averages of the various groups of costs making up this total. The direct relation of average total costs per pound of butterfat to volume of production is shown by the general trend of the individual total costs and by the relatively close fit to the line of the graph of the averages for each production class. At the same time, the influence of factors other than volume of production is shown by the scatter of the individual total costs about the average cost for each class, and by their dispersion from the line of the graph.

From the graph of total costs given in Fig. 1 it will also be noted that the average for the production class "2,000–2,500 tons" is displaced from the position one would expect it to occupy in relation to the same average for the other production classes. This displacement arises largely from the

relatively high average cost of manufacturing wages for this class (see Fig. 3). The creameries in this class are also distinguished by the facts that the average number of suppliers per company is relatively high and the average

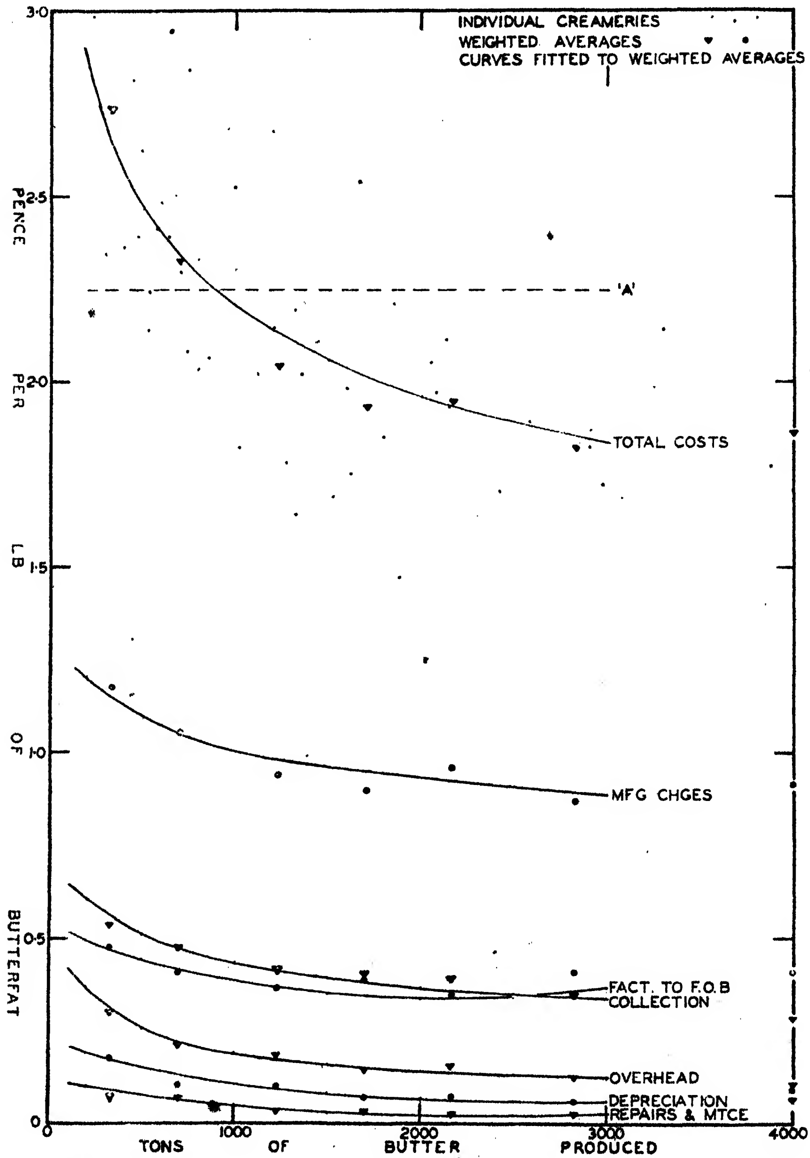


FIG. 1.—Buttermaking-costs per pound of butterfat for the 1937–38 dairying season in relation to volume of production. ("A" = allowance for total costs of manufacture made in the determination of the guaranteed price.)

butterfat delivered per supplier is relatively low (see Table 1). It seems probable that part of the increase in average manufacturing wages for the class "2,000–2,500 tons" is caused by these facts.

An interesting point is made clear in Fig. 1 on the data as it stands, the average creamery producing more than 900 tons during this season in effect received a premium on its net income from buttermaking under the guaranteed price because of its lower average working-costs.

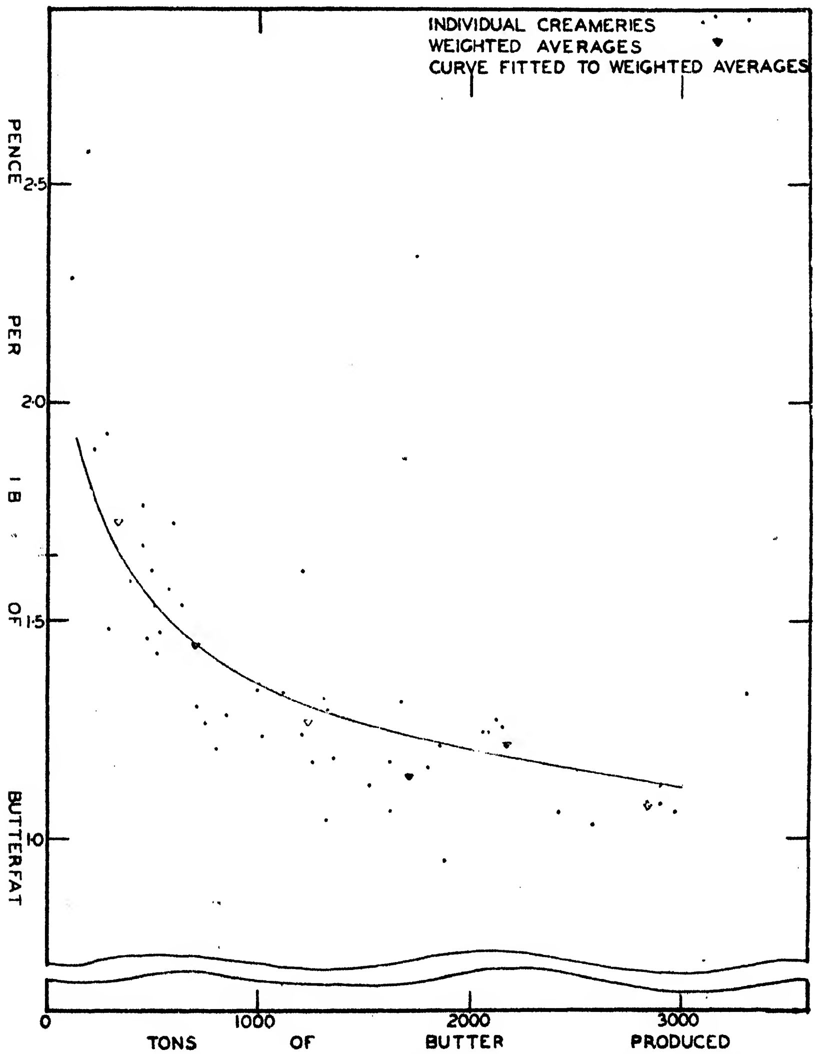


FIG. 2.—Graph of total costs per pound of butterfat *less* cream-collection and *less* charges factory to f.o.b. in relation to volume of production.

The costs per pound of butterfat of cream-collection and charges factory to f.o.b. are items which contribute largely to the scatter in total costs noted above. A creamery's unit cost of cream-collection is determined mainly by the size and geographical nature of its territory, while its charges factory to f.o.b. per unit depend almost entirely on the creamery's distance from its grading port. It may be noted here that, because a large creamery's territory is usually more concentrated and so permits full loads being carried by the

TABLE II

Production Class.	Number of Companies.	Average Manufacturing Charges.	Average Overhead Charges.	Average Depreciation.	Average Repairs and Maintenance.	Sub-total.	Average Collection-costs.	Average Charges Factory to f.o.b.	Total.
(a) Working-costs per Pound of Butterfat of Forty-nine Creameries in the Auckland and Wellington Provincial Districts for the Dairying Season, 1937–38									
Tons.		d.	d.	d.	d.	d.	d.	d.	d.
Under 500	10	1·179	0·300	0·175	0·073	1·727	0·534	0·475	2·736
501–1,000	11	1·054	0·211	0·104	0·070	1·439	0·476	0·409	2·324
1,001–1,500	8	0·939	0·184	0·105	0·034	1·262	0·413	0·364	2·039
1,501–2,000	7	0·896	0·145	0·070	0·034	1·145	0·401	0·386	1·932
2,001–2,500	5	0·957	0·152	0·074	0·029	1·212	0·390	0·346	1·948
2,501–3,000	5	0·868	0·126	0·060	0·027	1·081	0·345	0·404	1·830
Over 3,000	3	0·912	0·102	0·092	0·067	1·173	0·282	0·405	1·860
(The graphs of Figs. 1 and 2 are based on the above data)									
(b) Working-costs per Pound of Butterfat, expressed as a Percentage of the Total Cost for each Class									
Tons.		Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Under 500	10	43·1	11·0	6·4	2·6	63·1	19·5	17·4	100·0
501–1,000	11	45·3	9·1	4·5	3·0	61·9	20·5	17·6	100·0
1,001–1,500	8	46·1	9·0	5·1	1·7	61·9	20·2	17·9	100·0
1,501–2,000	7	46·4	7·5	3·6	1·8	59·3	20·7	20·0	100·0
2,001–2,500	5	49·1	7·8	3·8	1·5	62·2	20·0	17·8	100·0
2,501–3,000	5	47·4	6·9	3·3	1·5	59·1	18·8	22·1	100·0
Over 3,000	3	49·0	5·5	4·9	3·6	63·0	15·2	21·8	100·0

cream-lorries, &c., for the greater part of their trips, there would be a tendency for collection-costs to be lower with a large creamery than with a smaller creamery. However, it is doubtful whether the influence of this consideration would be as great as those referred to above.

The relative importance of the cost of cream-collection and charges factory to f.o.b. is apparent from the data, and together they averaged from 36·9 per cent. up to 40·9 per cent. of the total costs for this season. Fig. 1 shows a relation between cream-collection costs and volume of production and also between charges factory to f.o.b. and volume of production, but in view of the above remarks these relations can only be regarded as applying to the particular group of creameries included in this study. It is unlikely that they would be repeated with a different group of creameries.

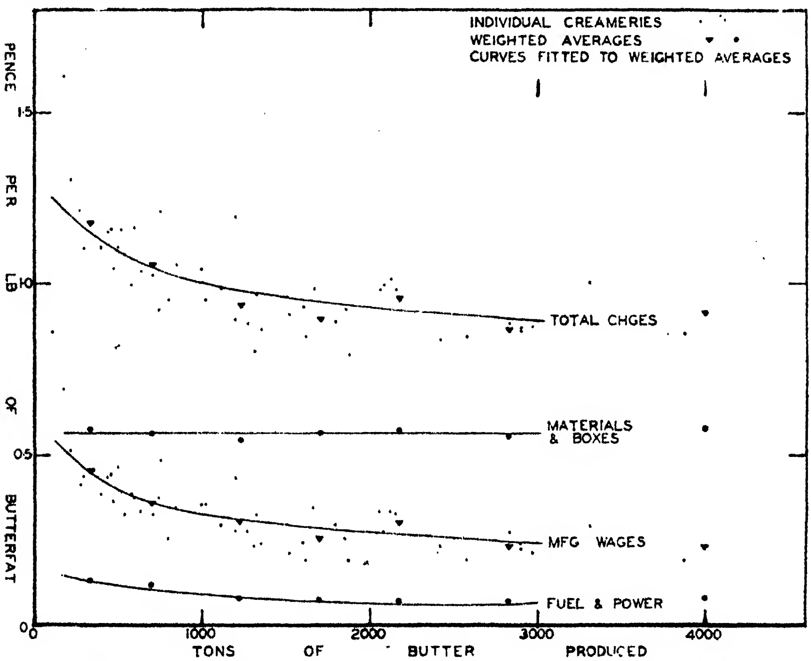


FIG. 3.—Manufacturing charges per pound of butterfat for the 1937–38 dairying season in relation to volume of production.

TABLE III.—MANUFACTURING CHARGES PER POUND OF BUTTERFAT OF FORTY-NINE CREAMERIES IN THE AUCKLAND AND WELLINGTON PROVINCIAL DISTRICTS FOR THE DAIRYING SEASON, 1937–38

Production Class.	Number of Companies.	Average Materials and Boxes.	Average Manufacturing Wages.	Average Fuel and Power.	Average Sundry Charges.	Average Total Charges.
Tons.		d.	d.	d.	d.	d.
Under 500 ..	10	0·576	0·457	0·133	0·013	1·179
501–1,000 ..	11	0·564	0·358	0·124	0·008	1·054
1,001–1,500 ..	8	0·547	0·301	0·082	0·009	0·939
1,501–2,000 ..	7	0·563	0·252	0·078	0·003	0·896
2,001–2,500 ..	5	0·572	0·300	0·075	0·010	0·957
2,501–3,000 ..	5	0·556	0·233	0·073	0·006	0·868
Over 3,000 ..	3	0·580	0·237	0·087	0·008	0·912

(The graph of Fig. 3 is based on the above data)

If the costs per pound of butterfat of cream-collection and charges factory to f.o.b. are excluded and only the combined unit costs of manufacturing, overhead, depreciation, and repairs and maintenance are plotted, the graph of Fig. 2 is obtained. Here not only is the dispersion of the individual costs considerably reduced (the average deviation of the data of Fig. 2 being 0·25d. as against 0·35d. for total costs), but the nature of the relation between costs and volume of production is also made clearer. When the influence of cream-collection and charges factory to f.o.b. is eliminated, the fall in unit cost with increased volume of production is, in fact, more gradual than is shown by the data as presented in Fig. 1.

Manufacturing charges (which cover the cost of wages, boxes, fuel and power, and materials other than butterfat) are the most important single group of costs, averaging from 43 per cent. up to 49 per cent. of the total average cost of manufacturing and marketing to f.o.b. It is this group of costs which is mainly responsible for the connection between total unit costs and volume of production. As shown in Fig. 3, within the group manufacturing charges, manufacturing wages per pound of butterfat decrease markedly with an increase in volume of production, and there is a smaller fall in unit fuel and power costs as production increases. As would be expected, the cost per pound of butterfat of materials and boxes shows no relation to volume of production

In addition to the fall in manufacturing charges per pound of butterfat caused by increased volume of production, Fig. 1 shows that an increased output is also accompanied by similar, but smaller, falls in the average costs per pound of butterfat of depreciation, repairs and maintenance, and overhead charges.

The data for depreciation costs and repairs and maintenance costs showed a fairly small dispersion about the average line of the graph, a fact which indicated that, as a whole, the companies surveyed were working to much the same standard in their expenditure on these items.

Because the amount of work to be done in a dairy company's office is affected more by the *number* of suppliers than by the quantity of butterfat each supplier delivers, the fall in unit overhead charges does not seem to be directly connected with the creamery's volume of production. In Table I it is shown that the average quantity of butterfat delivered per supplier tends to increase as the output of the creamery increases—that is, on the average, a large creamery has fewer suppliers in proportion to its size than has a small creamery. It seems, therefore, that to a large extent the reduction in overhead charges per pound of butterfat with increased production is directly connected with the fact that, as the creamery's output increased, the individual supplier's butterfat deliveries also tended to increase.

The dispersion of the individual company's unit cost of overhead charges was considerably greater than the dispersion of the unit costs of depreciation and repairs and maintenance, the dispersion being much wider below 1,000 tons than above that output. The probable explanation for this dispersion is that it is due to variations in the average quantity of butterfat handled per supplier as between the different creameries.

PAY-OUTS

A creamery's average gross income per pound of butterfat does not vary with its output, but, because total costs decrease as production increases, the average amount per pound of butterfat available for distribution to a company's suppliers shows a definite increase with increased production. These relations are shown graphically in Fig. 4.

This "amount available for distribution" may be regarded for practical purposes as being identical with "pay-out." In practice, to arrive at the pay-out, the amount available for distribution is increased slightly by

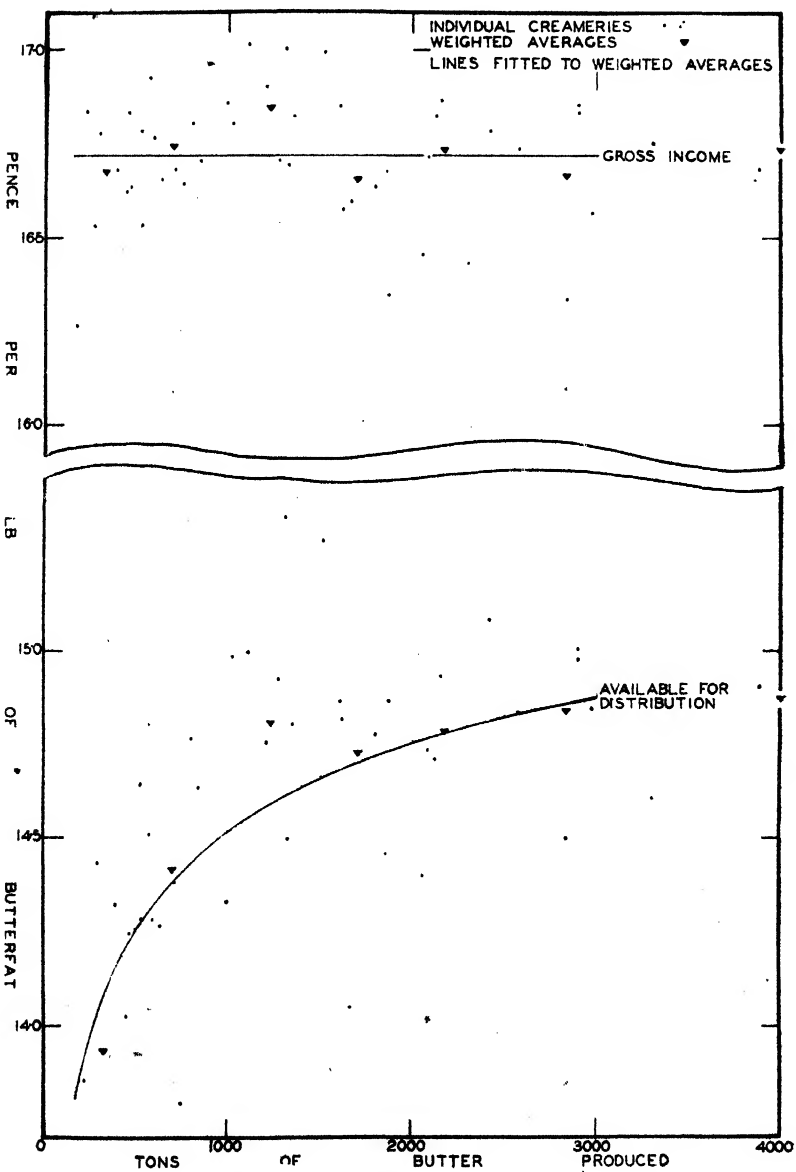


FIG. 4.—Gross income per pound of butterfat and amount available for distribution per pound of butterfat for the 1937–38 season in relation to volume of production.

income from subsidiary activities and decreased slightly by amounts put to reserve and amounts paid out as dividends on share capital.

TABLE IV.—GROSS INCOME FROM BUTTERMAKING PER POUND OF BUTTERFAT AND AMOUNT AVAILABLE FOR DISTRIBUTION PER POUND OF BUTTERFAT FOR FORTY-NINE CREAMERIES IN THE AUCKLAND AND WELLINGTON PROVINCIAL DISTRICTS FOR THE DAIRYING SEASON 1937–38

Production Class.	Number of Companies.	Average Gross Income.	Average Amount available for Distribution.
Tons.		d.	d.
Under 500	10	16·672	13·936
501–1,000	11	16·742	14·418
1,001–1,500	8	16·848	14·809
1,501–2,000	7	16·656	14·724
2,001–2,500	5	16·731	14·783
2,501–3,000	5	16·663	14·833
Over 3,000	3	16·731	14·871

(The graph of Fig. 4 is based on the above data)

As shown in Fig. 4, the amount available for distribution varied widely as between different companies within each production class. This is caused partly by variations between these companies in their overruns and average gradings, and partly by the effect of factors other than volume of production on costs of manufacture, &c., to f.o.b. However, the trend of the data is clear from the graph, and this, together with the trend of the averages for each production class, confirms the general statement made above.

CONCLUSION AND DISCUSSION

In brief, the main conclusion to be drawn from the above data is that, as production increases, the average creamery's total costs per pound of butterfat decrease and its pay-out per pound of butterfat to the supplier increases. This confirms similar conclusions reached by the author in an earlier study(1).

In comparison with the proportion of the gross factory income returned to the creamery supplier in other countries(2), the proportion of the gross factory income returned to the creamery-supplier in New Zealand is high. It seems, therefore, that the average creamery of a given size has little scope for a reduction in its total expenditure on manufacturing and marketing to f.o.b.

Within the creamery, the reduction in unit costs due to increased production arises mainly from the fall in the cost of manufacturing wages per pound of butterfat with increased production. This fact emphasizes the importance of volume of production and also emphasizes the necessity for utilizing all labour within the factory in the best possible way.

The facts that costs decrease and pay-outs increase with increased production are characteristic of most manufacturing industries, and are known in general terms to those responsible for the direction of the dairy industry in New Zealand. It was the recognition of these facts which, in spite of the threefold increase in butter-production between 1921 and 1937, led the dairy industry as a whole not to increase the number of butter-factories in operation during this period, but rather to increase their average production. In fact, the number of creameries in operation in 1937 was fourteen less than in 1921, although the total butter-production increased from approximately 63,000 tons up to approximately 180,000 tons in the same period.

Logically, the next step in the application of the results of this paper is to determine exactly why the gross returns and/or working-costs of some creameries fall below the averages given, while the same figures for other creameries are above them.

Because gross returns are dependent on overruns and butter quality, the reasons for the variations in gross income as between different creameries will be primarily technical. To determine these reasons, field studies would have to be made of the technical efficiency of buttermaking as between different companies, the quality of supplies and materials, and other similar matters. So far as costs are concerned, such investigations would be mainly of an engineering and economic character. From the engineering point of view they would involve comparisons of the efficiency of the equipment used in different creameries, the suitability of the layout of the factory, &c., while the economic approach would entail studies of management, the efficiency of labour, the employment of capital invested, the organization of the companies, and so on. Such studies and comparisons would necessarily have to be co-ordinated because they are inter-related and would react one on another. No clear-cut line of demarcation could be drawn between them.

Though some work has been done along the above lines, much still requires to be done, particularly in regard to the study of the engineering and economic problems of the industry. If investigations as outlined above were made, and the results put into practice, they could undoubtedly lead to a further increase in the efficiency of the manufacturing side of the dairy industry in New Zealand.

ACKNOWLEDGMENTS

The thanks of the author are due in particular to Professor Wm. Riddet, Director, Dairy Research Institute, for his encouragement and helpful advice. The author also is indebted to Dr. W. M. Hamilton, of the Department of Scientific and Industrial Research, and to Dr. H. R. Whitehead and Dr. F. H. McDowall, of the Dairy Research Institute, for their helpful criticism.

REFERENCES

(1) TASKER, J. F.: The Costs and Capitalization of North Auckland Creameries during 1935–36. *The Accountants' Journal* (Aug., 1938).

(2) Report on Butter and Cheese Factory Production Costs. *Dairy Industry Control Board, Pretoria, South Africa.* (1932.)

An Economic Analysis of Creamery Operations in New Brunswick. *Dominion Department of Agriculture, Canada.* (1934.)

Cost of operating Creameries in the Prairie Provinces, 1933–34 (Preliminary). *Department of Agriculture, Ottawa, Canada.*

RICHARDS, A. E.: Farmers' Business Organizations in Canada. *Department of Agriculture, Canada* (1934), *Bulletin No. 173.*

MIGHELL, A., and QUINTUS, P. E.: Financial Management of Farmers' Creameries. *Iowa Agricultural Experiment Station* (1936), *Bulletin No. 351.*

A GRASS-CLEANING MACHINE

By W. G. WHITTLESTON, Animal Research Station, Wallaceville

[Received for publication, 13th September, 1944]

IN work involving the chemical analysis of dried grass the presence of fæces and other contaminants is undesirable. It was found by workers at the laboratory that shaking the grass samples in a box enabled a separation between the grass and denser components to be made. However, the shaking required a peculiar motion which was tiring and not easily learned. An attempt was made, therefore, to construct a machine based on a rough analysis of the motion produced by hand which effected a separation. The following machine has been found to effect a good separation between dried grass and denser contaminants.

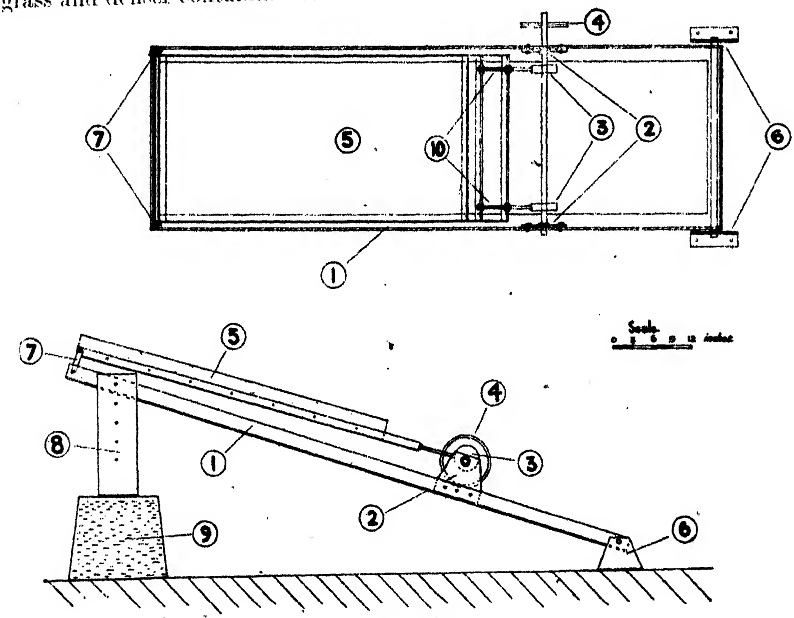


FIG. 1

The machine consists essentially of an inclined tray shaken by an eccentric drive in such a way that the lower portion of the tray has a complete circular motion imparted to it while the upper portion moves through a short arc of a circle. Figure 1 illustrates the main components :—

(1) An *Angle-iron Frame*, 2 in. wide by 2 in. deep, welded at the corner joints.

(2) *Steel Brackets*, which carry the bearings of the main driving-shaft.

(3) *Eccentrics* ($3\frac{3}{4}$ in. external diameter with a throw of $\frac{3}{8}$ in.). (In the model at present in use a single eccentric is used. This permits "whipping" of the driving shaft under load and the tray tends to tilt sideways slightly. If a single eccentric is used the shaft bearings must be self-aligning.)

(4) *Driving Pulley :* This pulley is a heavy casting which acts as a fly-wheel. The shaft should run about 400 r.p.m. The machine is driven by a $\frac{1}{4}$ h.p. motor via a Vee belt.

(5) *Wooden Tray*, 4 ft. by 2 ft., mounted in an angle iron (1 in. by 1 in.) frame. The tray is 3 in. deep and the bottom is covered with calico. This covering is essential for efficient performance. The tray is of ½ in. timber for the sides and has a three-ply bottom. Lightness is essential.

(6) *Supporting Brackets:* These heavy iron brackets are held firmly by large bolts to the concrete floor on which the machine is mounted. It is essential that this part of the machine be thoroughly robust. The frame is held in place by a 1 in. steel shaft passing through the brackets.

(7) *Shackles* holding the top end of the tray. These should be fitted with ball bearings, which are spaced 3 in. between centres. The shackles are at right angles to the main frame (1), when the eccentrics are in the middle of the throw.

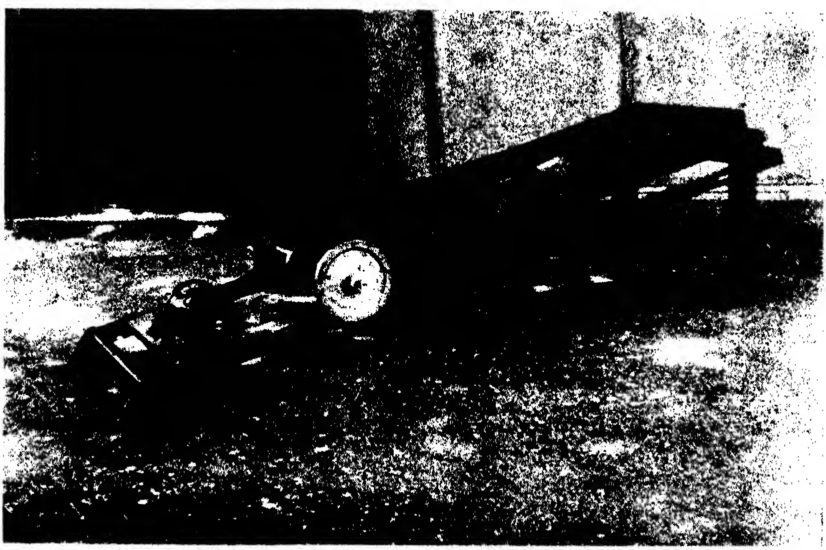


FIG. 2

(8) *Supporting bracket* for the top end of the frame. This is drilled with a series of bolt holes enabling the angle of tilt to be adjusted. Bolts pass through these holes into slots in the main frame. This bracket is fitted rigidly to a concrete block (9).

(10) *Bolts* connecting the eccentrics to the tray. These enable adjustment to the travel of the tray to be made.

Dimensions:—

Main Frame: 87 in. by 26 in. 2 in. by 2 in. angle iron.
Tray Frame: 54 in. by 24 in. 1 in. by 1 in. angle iron.
Top supporting bracket: 18 in. high by 6 in. wide; 26 in. between arms.
Shackles: 3 in. between bearing centres; 1 in. wide.
Driving shaft: 1 in. diameter.
Supporting shaft: 1 in. diameter.
Eccentrics: 3¾ in. external diameter; ¾ in. throw.
Driving pulley: 7½ in. diameter (to take Vee belt).
Bottom supporting brackets: 4½ in. high by 7 in. wide at base.

Figure 2 shows a general view of the machine.

OPERATION

The dried grass is placed about the middle of the oscillating tray. The grass moves to the top of the tray while the denser contaminants move to the bottom, where most of the material collecting is thrown out due to the vertical motion at this end of the tray. Depending on the nature of the sample, the machine may be operated continuously or with batches of material. The angle of tilt for the tray should be adjusted for the type of sample to be handled. It has been found that this angle and the nature of the surface of the tray are critical for efficient operation. The throw of the eccentric is also important.

Although the machine has been used only for separating fæces, &c., from dried grass, there are no doubt other applications for which it may be useful. It has been noticed that it removes some of the small weeds which are usually associated with grass. The action is probably due to the difference in density of the fractions and to the difference in friction between these fractions and the tray surface.

ACKNOWLEDGMENTS

The writer is indebted to Mr. H. G. Sawtell, of this Laboratory, for his assistance in the construction of the apparatus, and to Mr. J. E. V. Simpson, who carried out trials with an experimental model and operated the final machine. Thanks are due to Mr. J. B. Swan, of this Laboratory, who first observed that the cleaning of dirty grass could be affected by shaking in a box by hand.

THE CONTROL OF COBALT DEFICIENCY AT SHERRY RIVER, NELSON

THE VALUE OF MINUTE QUANTITIES OF COBALT SULPHATE

By H. O. ASKEW, Cawthron Institute, Nelson

[*Received for publication, 5th September, 1944*]

Summary

Hoggets were maintained in a satisfactory state of health over a period of nearly two years on a cobalt-deficient pasture by the use of annual applications of 2 oz. cobalt sulphate per acre, or by a biennial dressing of 4 oz. cobalt sulphate.

The annual dressing of 2 oz. cobalt sulphate gave rather higher live-weight gains in the hoggets in the second season than was the case with the sheep on the plot receiving one application of 4 oz. cobalt sulphate.

The best result was obtained from the area top-dressed previously with cobaltized superphosphate containing 16 oz. cobalt sulphate equivalent per acre. Sheep on this treatment, even in the third season after application of the fertilizer, showed higher live-weights and greater wool-weights than those on the other treatments.

INTRODUCTION

THE control of bush sickness and similar ailments by the use of cobalt compounds is well established, but precise information as to the minimum quantities of cobalt that will give satisfactory results is not available. An attempt to provide part of this information for the conditions existing at Sherry River, Nelson, forms the subject-matter of this paper. In other parts of New Zealand annual applications of cobaltized fertilizer to provide

the equivalent of 4 oz. of cobalt sulphate per acre have been recommended as sufficient. Whether it would be possible to reduce this to a lower figure does not appear to have been determined. In the experiment to be described the annual application of cobalt was equivalent to 2 oz. of cobalt sulphate per acre. A cobaltized fertilizer (experimental batch) was also included for comparison.

EXPERIMENTAL

Superphosphate at the rate of $1\frac{1}{2}$ cwt. per acre was used on each plot, consisting of 2 acres on which five animals were run. The smaller cobalt applications were made by diluting cobaltized superphosphate with ordinary

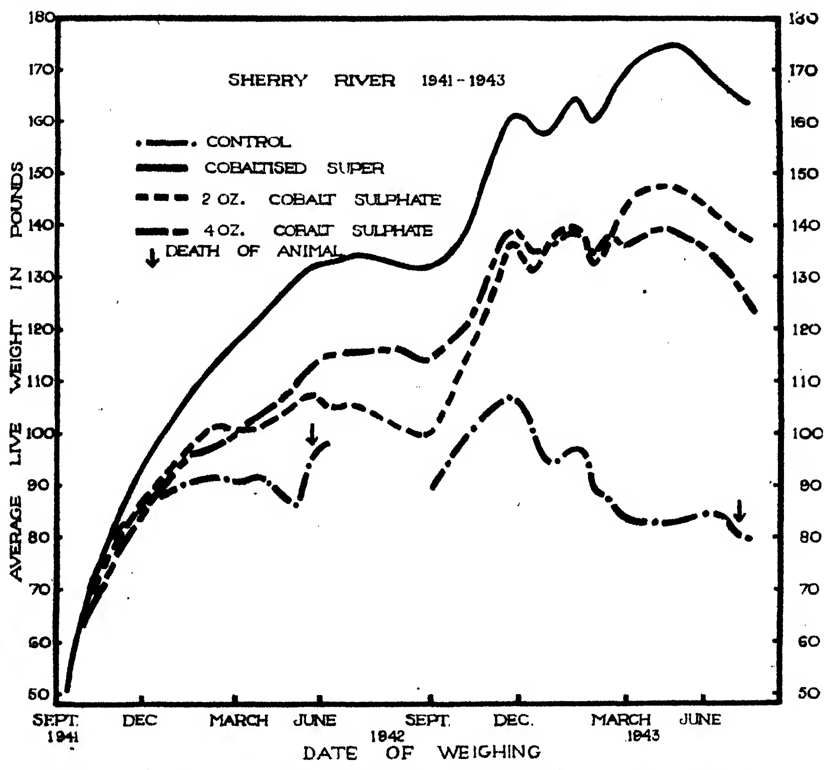


FIG. 1.—Average live-weight, in pounds, of sheep at Sherry River, 1941–43.

superphosphate. The quantities of cobalt sulphate equivalent applied were as follows :—

(1) 16 oz. cobalt sulphate* per acre (cobaltized superphosphate) :
(2) 2 oz. cobalt sulphate* per acre :
(3) 4 oz. cobalt sulphate* per acre :
(4) Control (no cobalt).

The cobaltized superphosphate had been applied on 27th August, 1940. The small cobalt applications were given on 5th September, 1941. A second application of the 2 oz. rate was made on 8th September, 1942, but on this occasion the 4 oz. plot received superphosphate without any cobalt. In both seasons the control and the 16 oz. cobalt sulphate plot (cobaltized superphosphate) received ordinary superphosphate at $1\frac{1}{2}$ cwt. per acre. The plots

* As hydrated cobalt sulphate $CoSO_4 \cdot 7H_2O$.

used for the 4 oz. and 2 oz. cobalt sulphate treatments had been treated in the 1940–41 season with 2 tons of ground limestone per acre. The control plot was similarly treated on 26th August, 1941, but the cobaltized superphosphate plot (16 oz. cobalt sulphate in 1940) remained without lime treatment during the period of this experiment.

Romney cross woolly hoggets were weighed, tagged, and drafted on to the experimental plots on 18th September, 1941, in groups of five animals of uniform average live-weight of approximately 51 lb. Five sheep for use as replacements if necessary were put on to a field where they would not have access to cobaltized lick or pasture. The animals on the experimental plots were weighed at fortnightly intervals so far as could be arranged, the course of the changes in weight being shown graphically in Fig. 1; data at selected periods are given in Table I.

TABLE I.—AVERAGE LIVE-WEIGHTS, IN POUNDS, OF SHEEP AT SHERRY RIVER, 1941–43

Date.	Control.	2 oz. Cobalt Sulphate per Acre.	4 oz. Cobalt Sulphate per Acre.	Cobaltized Superphosphate.
18/9/41	50·6	51·0	50·8	50·6
1/12/41	84·4	35·2	82·2	91·6
11/1/42	88·8	96·6	95·4	108·8
21/3/42	91·8	104·4	104·0	122·0
11/5/42	95·9	108·3	115·0	133·1
21/6/42	..	105·4	115·6	135·0
27/8/42	..	99·5	113·8	131·2
6/9/42	90·6*	102·0	117·0	134·0
15/11/42	107·6	136·0	139·7	161·8
3/1/43	95·7	137·5	137·0	162·0
14/2/43	88·9	137·2	138·4	166·0
30/4/43	82·8	146·3	139·4	174·1
30/5/43	81·6	144·9	136·4	170·4
27/6/43	84·2	140·4	132·2	167·8
24/7/43	79·8	137·2	124·4	163·8

* The average live-weight of these sheep on 18th September, 1941, was 51·3 lb.

The sheep increased in weight satisfactorily until the middle of January, 1942, when the control sheep were lagging behind and had become almost stationary in weight. Animals on the other treatments continued to increase in weight, especially those on the area treated with cobaltized superphosphate. By the end of February some of the control sheep showed signs of sickness, and by the end of March two of the five were definitely losing weight. On 28th April one of them died. Only two of the remaining sheep were now apparently healthy. All the other sheep were in a very healthy state, the live-weights at the end of the autumn being, in decreasing order, cobaltized superphosphate, 4 oz. cobalt sulphate, and 2 oz. cobalt sulphate.

Owing to the poor condition of the control group, and to some of them having been treated with cobalt over the winter, the five spare sheep were introduced as controls on 6th September, 1942. The previous controls were removed from the experiment. A further 2 oz. cobalt sulphate equivalent was given to the area treated at this rate in the previous season, thus bringing up the total cobalt application to the same amount on the two cobalt sulphate treated plots. The live-weight records show that the sheep on the 2 oz. cobalt sulphate plot at the end of the winter were lower in weight than those on the 4 oz. treatment. After the application of the second 2 oz. of cobalt sulphate the animals on this treatment gained in weight at an appreciably greater rate than those on the 4 oz. treatment, and by the end of December, 1942, the latter animals were the lowest in weight of those on cobalt-treated

plots. The animals on the 2 oz. treatment remained heavier than those on the 4 oz. treatment until the end of the season.

The control sheep were in comparatively poor condition, although they were not exhibiting any signs of cobalt deficiency. At the beginning of March, 1943, the appearance of the sheep was as shown in Figs. 2 to 5. All the treated sheep were in fat condition, while some of the control sheep were definitely sick, as shown by their inability to be driven. Although the difference in weights between the groups on the 2 oz. and 4 oz. cobalt sulphate treatments was not great, those on the 2 oz. treatment were considered to have a better finish. Sheep on the cobaltized superphosphate area were fat. Over the autumn and winter, up to August, the sheep on the cobalt-treated areas maintained their weight fairly satisfactorily, but the control group became very poor in condition, and by the end of July were on the average nearly 28 lb. lighter than their maximum weight in November, 1942.

From the data presented it is clear that the small applications of cobalt have satisfactorily maintained the sheep in health; two applications of 2 oz. cobalt sulphate per acre in two succeeding seasons gave slightly better results than one application of 4 oz. intended to last over two seasons.

In addition to the differences in live-weight between the various groups of sheep there was a difference in the yields of raw wool. The average weights of wool cut in the two seasons were as follows:—

Season.	Control (no Cobalt).	2 oz. Cobalt Sulphate per Acre.	4 oz. Cobalt Sulphate per Acre.	Cobaltized Superphosphate.
	lb.	lb.	lb.	lb.
1942	5·3	5·8	5·3	5·9
1943	8·2	9·9	10·4	11·9

In the first season there was little time for the cobalt treatments to exert any effect on wool-growth, the sheep being shorn at the beginning of December. In the second season increases in yield of wool due to cobalt treatment were very marked, the yield being particularly high on the cobaltized superphosphate plot, where it represented an average gain of 3·7 lb. per head over the control.

During the period of the experiment pasture samples were obtained from each of the plots, and these were subsequently examined for cobalt content, with the results shown in Table II. After the first dressings were given on 5th September, 1941, the cobalt contents of the pastures were high, as revealed by the samples taken on 1st October. The cobalt content of the control pasture was at a level, which, if continued, would be expected to lead to development of cobalt deficiency symptoms in sheep grazing on it. As shown by the data of Table II, the control pasture remained at a low figure throughout the experiment. Later in the 1941–42 season the cobalt contents of the top-dressed pastures, except the one top-dressed with cobaltized superphosphate, fell to almost as low values as those of the control, although in the autumn they tended to increase somewhat. After the second application of 2 oz. cobalt sulphate the cobalt content of this pasture was greatly increased and remained appreciably higher than the control figure throughout the season. The plot which received the 4 oz. application the previous season was again appreciably richer in cobalt than the control one. The most consistently high contents of cobalt have been shown by the samples from the plot top-dressed in 1940 with cobaltized superphosphate supplying the equivalent of 16 oz. of cobalt sulphate per acre.

FIG. 2.—Control sheep, no cobalt plot, on 2nd March, 1943.

FIG. 3.—Sheep on plot top-dressed with 2 oz. cobalt sulphate per acre in 1941–42 and in 1942–43, on 2nd March, 1943.

FIG. 4.—Sheep on plot top-dressed with 4 oz. cobalt sulphate per acre in 1941-42, on 2nd March, 1943.

FIG. 5.—Sheep on plot top-dressed with 16 oz. cobalt sulphate per acre (cobaltized superphosphate) in 1940, on 2nd March, 1943.

TABLE II.—COBALT CONTENT OF SHERRY RIVER PASTURES, 1941–43
(Expressed as parts per million (p.p.m.) of cobalt (Co) in dry matter)

Date of Sampling.	Control (no Cobalt).	2 oz. Cobalt Sulphate per Acre.	4 oz. Cobalt Sulphate per Acre.	Cobaltized Superphosphate.
	p.p.m.	p.p.m.	p.p.m.	p.p.m.
1/10/41	0·030	0·22	0·37	..
23/10/41	..	0·060	0·13	0·14
11/11/41	0·027	0·038	0·058	0·13
5/12/41	0·030	0·032	0·036	0·082
4/2/42	0·026	0·053	0·056	0·093
24/2/42	0·028	0·049	0·045	0·082
30/3/42	0·030	0·063	0·079	0·11
14/5/42	0·059	0·042	0·084	0·12
16/10/42	0·035	0·262*	0·14	0·16
17/11/42	0·034	0·068	0·062	0·17
16/12/42	0·038	0·056	0·065	0·093
2/3/43	0·050	0·092	0·092	0·20
6/4/43	0·041	0·079	0·053	0·074

* After second application of cobalt sulphate.

Comparison of the data for cobalt contents of the pastures with the live-weights of the sheep shows a very satisfactory correlation—the heavier sheep being associated with higher cobalt content of the pasture.

The results recorded above show that two annual applications of 2 oz cobalt sulphate per acre give in the case of hoggets on the cobalt-deficient soil of the Sherry River rather better results than one application of 4 oz. cobalt sulphate. At the end of the first season, however, the 4 oz. application showed a superiority over the 2 oz. application. In neither case was the effect on live-weight increase of the sheep so pronounced as with cobaltized superphosphate providing 16 oz. cobalt sulphate equivalent per acre. This treatment, even in the third season of application, showed marked improvement over the smaller amounts of cobalt sulphate.

ACKNOWLEDGMENTS

Grateful thanks are due to Mr. M. C. Haines, of Sherry River, for the use of his fields for the purpose of this trial, and to Mr. Haines and his sons for their careful weighing of the sheep. Thanks are also expressed for the help given in the preparation of samples by Mr. Ian White. Miss J. Watson kindly determined the cobalt contents of the pasture samples.

THE NEW ZEALAND

JOURNAL OF SCIENCE

AND

TECHNOLOGY

Editor: D. Cairns, M.Sc., Department of Scientific and Industrial Research, Wellington

VOL. 26, SEC. A FEBRUARY, 1945 NUMBER 5

SOME STUDIES ON THE PROPERTIES OF RUBBER USED IN DAIRY EQUIPMENT

PART I

By W. G. WHITTLESTON, Animal Research Station, Wallaceville

[*Received for publication, 29th August, 1944*]

Summary

(1) A flexing test for rubber teat-cup liners ("inflations") has been developed. The test requires the application and release in a 50 : 50 ratio of a vacuum of 20 in. of mercury at the rate of 58 per minute. The rubber is held under a constant tension of 12 lb. during the test, and the result is taken as the total length of cracking observed after 1,000,000 flexings.

The influence of hardness, wall thickness, method of manufacture, tension, surface, filler, and butterfat on the flexing properties of "inflations" has been examined.

(2) A test for rubber tubing as used on milking machinery has been devised. The tubing to be tested is fitted between two nipples, one of which swings with respect to the other so that the tube is bent about its middle through an angle of ± 90°. The tube is subjected to a vacuum of 20 in. of mercury throughout the test and the end-point is automatically recorded as the point at which a hole equivalent to $\frac{1}{32}$ in. in diameter develops through the wall. The influence of butterfat on bending is examined and the test applied to experimental tubing described later in the paper.

(3) A study has been made of the influence of butterfat on rubber of various types. The following factors have been examined:—

(*a*) The influence of butterfat on tensile strength with different rubber stocks:

(*b*) The effect of butterfat on heat-ageing resistance:

(*c*) The effect of butterfat on light-ageing resistance:

(*d*) The effect of possible methods of removing butterfat on light-ageing resistance and flexing properties.

(4) An examination has been made of the properties of two types of "soft" inflation. The following methods related to conserving rubber have been examined in the laboratory and in the field:—

(*a*) The addition of reclaimed rubber to inflation rubber stocks. The effect of reclaim on various physical properties of the rubber has been examined:

(*b*) Experimental rubber stocks with a range of filler content have been tested:

(*c*) The use of a smooth external finish on an inflation has been tried:

(*d*) Carbon black as an inflation filler has been tested:

(*e*) The use of whole-tire and other types of reclaim in tubing has been studied:

(*f*) Carbon black as a filler for tubing has been tested and the effect of butterfat on this type of rubber examined:

(*g*) A simple test for the tendency of tubing to collapse is described:

(*h*) The results of Geer oven ageing tests on typical New Zealand rubbers are given, together with analyses of such rubbers:

(*i*) An experimental tubing has been tried out in which a thin internal layer of normal rubber is bonded to a thicker wall of whole-tire reclaim.

THE ACCELERATED AGEING OF RUBBER

INTRODUCTION

THE following paper presents results obtained from work done with a view to assisting in the conservation of rubber used by the dairy industry of New Zealand, with special reference to rubber used on milking machinery. A survey of the available literature gave little information of any value in assessing the effect of the many factors liable to accelerate the ageing of rubber components used in the presence of milk. In the case of the teat-cup liners of milking-machines, where a strong flexing action takes place, it was possible, of course, to use results obtained with the conventional flex-testing equipment. However, such equipment is of little use for testing the finished article. Following the usual procedure in such work, tests have been devised which pick on one or two of the chief factors influencing ageing in a particular component and these factors have been standardized and subjected to measurement.

Two rubber components of milking-machines which are subjected to rather unusual conditions are the teat-cup liners or inflations and the "claw" tubes. The former, during their useful life, are maintained under longitudinal tension and are stretched at least at one end over a metal ring. When in actual use during milking the inflation flexes at rates varying from 38 to 45 flexings per minute for periods of one to three hours, during which time it is in contact with warm milk. The claw tube conveys warm milk from the teat-cup to the claw and is subjected as the cups are applied to a cow to bending so as to cut off the vacuum. The rubber tube is usually folded back over a metal nipple either on the claw or the cup. Further, as the cups fall on the concrete floor from time to time or are slung over metal or wooden supports in the bail, the rubber is subject to frequent knocks. The rubber is often wet when so treated, so that resistance to cutting and knocking is essential for a satisfactory life.

The results of our work will be discussed under the headings of these two components—namely, "inflations" and claw tubes—as the requirements of these, while parallel in some respects, are quite different in others. The other important rubber constituents of milking-machines, the air and milk tubes, will be discussed under general methods for conserving rubber.

THE PROPERTIES OF RUBBER USED FOR THE MANUFACTURE OF MILKING-MACHINE INFLATIONS

Because of the significance of flexing in the normal life of inflations, this test was chosen first as a means of inquiring into the suitability of different rubber stocks for use in the manufacture of this component.

The flexing test was carried out on a machine consisting of a double port slide valve which applied and released in each of two sets of eight connecting tubes a vacuum of 20 in. 58 times per minute. The vacuum phase equalled the atmospheric phase in duration. By means of two circular distributors the distances and size of tubing between the nipples carrying the inflations to be tested and the slide valves were made equal so that all samples were tested under identical conditions. The top end of the inflations under test was affixed with a normal teat-cup nipple connected to the slide valve. The bottom end was fixed by means of a similar nipple and ring to a 12 lb. weight, this weight being of the same order as that applied to an

inflation under normal field conditions when stretched in a teat-cup. The samples under test are covered to prevent light from influencing the test. The test is run continuously.

Before discussing the results of individual tests it is necessary to consider the criteria by which the end-point of the test is to be judged. In our preliminary tests the number of flexings required to produce a crack $\frac{1}{4}$ in. long were taken. This is a very inconvenient end-point, requiring, as it does, almost constant observation. It was therefore decided to note this end-point together with the total length (in inches) of the cracks formed after 1,000,000 flexings—a much easier measurement. Both tests were taken on an assortment of all types of rubber and shapes of inflation. Some eighty samples were so tested, and the correlation between the number of flexings required to produce a $\frac{1}{4}$ in. crack and the total length of cracks formed after 1,000,000 flexings determined. A correlation coefficient of −0·67 was found, an excellent figure when the large errors liable to arise in determining the flexings required to produce a $\frac{1}{4}$ in. crack are considered.

For all practical purposes the total length of the cracks formed after 1,000,000 flexings is taken as an index of the resistance of rubber to flexing.

On first examination it would be thought that two different properties were being measured. However, the correlation coefficient indicates that there is a fair proportion of common elements between the two end-points. That different properties are to some extent measured is shown by the hypothetical case of a rubber with poor tear resistance but excellent flexing properties. Such a rubber could perform 900,000 flexings before developing a $\frac{1}{4}$ in. crack. However, during the last 100,000 flexings this crack could spread the entire length of the sample. In practice, however, good tear resistance is required as well as resistance to flexing.

The following experiments show the influence of various factors on the flexing life of inflation rubber.

The Influence of Hardness

For this experiment two rubbers of different hardness made by the same firm were taken. The length of cracks formed after 1,000,000 flexings were as follows :—

—	Length of Crack (Inches).				Mean.	Shore Hardness.
Soft	5·3	5·0	6·7	0·4	4·4	37
Normal	2·3	0·0	0·3	0·2	0·7	48

The application of the "t" test to the significance of these results gives the following :—

The pooled variance V = 3·22.

Difference between means $\bar{d}$ = 3·7.

$t = \bar{d}/\sqrt{2V/n}$, where n = number of observations in each group.

$= 2·91$.

This indicates a significant difference between the groups (P = 5 per cent.).

There is apparently no advantage in using a soft rubber from the point of view of flexing life.

Wall Thickness

Four different kinds of rubber were chosen for this test. The inflations with a $\frac{7}{64}$ in. wall are described as "normal," those with a $\frac{3}{32}$ in. wall are described as "thin." The following are the results on a flexing test :—

—	Length of Crack (Inches).								Mean.
Normal	0·3	0·2	5·3	5·0	4·6	1·5	1·5	1·1	2·5
Thin	2·3	0·0	6·7	0·4	4·0	3·9	1·4	0·2	2·4

It is evident from inspection that there is no significant difference between these groups. Apparently wall thickness within the above limits does not influence flexing life.

A COMPARISON BETWEEN LIGHT MOULDED AND EXTRUDED INFLATIONS

The most commonly used inflation (the "soft" inflation) is a simple extruded tube with a wall thickness of $\frac{3}{32}$ in. or $\frac{7}{64}$ in., a length of $6\frac{1}{4}$ in., and an internal diameter of $\frac{7}{8}$ in. or $\frac{13}{16}$ in. Some firms, however, favour a light moulded inflation which is of approximately the same weight as a "soft" inflation but is shaped, usually with longitudinal ribs, and is vulcanized in a mould. The following figures compare the results obtained from three different makes of light moulded inflations of identical shape with the equivalent soft inflation :—

—	Length of Crack (Inches).						Means.
Soft	4·6	3·9	0·6	2·0	0·3	3·5	2·5
Moulded	5·0	4·3	2·3	0·1	0·8	1·0	2·3

There is no significant difference between these groups indicating that the light moulded inflation is not superior to the soft inflation in flexing properties.

THE INFLUENCE OF TENSION

It is of some practical importance to know what effect, if any, the tension on the rubber in the teat-cup has on its flexing life. In order to determine this, pairs of soft inflations of different makes were flexed under three different tensions, with the following results :—

Make.	Tension (Pounds).	Length of Crack (Inches).
A	24	0·5
B	24	0·1
A	12	0·3
B	12	3·5
A	2	1·0
B	2	4·5

These figures show no significant differences between groups.

In view of the importance of this point, a further experiment was carried out with the object of determining whether the release of tension on inflations between milkings is of value in extending the flexing life of the rubber. In normal flexing tests acceleration is obtained by continuous flexing. This could not be done in this experiment, so the usual hot-air oven ageing technique was used.

The apparatus used consisted of a small hot-air oven maintained at 70° C. and fitted with a fan which gave a uniform temperature and continuous recirculation of air. The oven was fitted with two sets of teat-cup nipples, one arranged to apply a fixed elongation to the samples under test, the other arranged so that a given percentage elongation could be applied to a set of inflations only when they were being flexed, the rubber being allowed to recover its normal length immediately flexing ceased.

Flexing was obtained by applying and releasing a 15 in. vacuum 60 times per minute for two evenly spaced two-hour periods per day.

All inflations in the test were marked with fine lines 2·00 in. apart.

The experiment was carried out using standard $\frac{7}{8}$ in. inflations of two makes. These were numbered 1–8 and divided as follows:—

Continuous tension	1. 3.	Make A.
	2. 4.	Make D.
Intermittent tension	5. 7.	Make A.
	6. 8.	Make D.

The elongation applied was 25 per cent.

The period of test was twenty-eight days.

Total flexing time, 112 hours.

Total flexings, 403,000.

Three criteria have been taken as an indication of performance. They are *permanent set* this is given in percentage increase in the distance between the marks. *Deformation—i.e.*, the deviation of the tube from circular. The figure is the difference between the axes measured externally in inches. For no deformation the axes are the same and the figure = 0.

Total Length of Cracks formed

Results :—

No.	Percentage Permanent Set.	Deformation.	Length of Crack (Inches).
1	11	0·16	0·0
2	9	0·18	2·2
3	12	0·14	0·15
4	13·5	0·17	3·35
5	2	0·12	0·65
6	2	0·11	0·55
7	1·5	0·10	0·0
8	2	0·12	0·9

Nos. 4 and 8 showed some tearing at the ends held by the nipples.

Averages for Two Groups :—

...	Percentage Permanent Set.	Deformation.	Length of Crack (Inches).
Continuous tension	11·4	0·16	1·43
Intermittent tension	1·9	0·11	0·53

Application of the "*t*" test to the above results shows that, while the differences in permanent set are highly significant (P = 1 per cent.), the differences between flexing resistances do not quite make the significant level (P = 5 per cent.). It would appear that the maintenance of a constant tension will only influence flexing life slightly, while, as is to be expected, it will have a definite effect on permanent set.

THE INFLUENCE OF EXTERNAL SURFACE

It was thought worth while to inquire into the effect of the external surface of a soft inflation on flexing life. The normal outer surface of such an inflation reflects the texture of the linen wrapping-cloth in which it has been cured. The inner surface, however, takes on the smooth nature of the metal mandrel used as a support during curing. Two pairs of inflations of different makes were taken and one of each turned "inside out" and subjected to flexing. The following were the results :—

Make.	Length of Crack (Inches).	
	Normal.	Inside out.
A	0·3	0·0
D	3·5	0·0

The differences are significant. As would be expected on general grounds, where the flexing surface is smooth the tendency to develop flex cracks is reduced.

TYPES OF FILLER

With a view to ascertaining the influence of filler on flexing life, a batch of experimental inflations was prepared in which the normal clay filler was replaced by carbon black. On a flex test in which the controls were the normal inflations made by the same company the following results were obtained :—

	Length of Crack (Inches).			
Normal	2·4	1·4	1·8	2·2
Carbon black	0·0	1·6	1·4	0·3
Difference	+2·4	−0·2	+0·4	+1·9

$S = 1·3$; $\bar{X} = 1·4$.

The differences do not reach significance ($P = 5$ per cent.).

In this connection differences between makes are interesting. Make A is a slightly harder rubber (shore hardness, 48·9) than make D (shore hardness, 47) :—

Make.	Length of Crack (Inches).						
A	0·0	0·8	0·1	0·0	0·3	0·0	0·6
D	1·4	0·2	2·4	1·4	3·5	1·8	2·2

The differences are highly significant ($P = 1$ per cent.). The most noteworthy difference between the two rubbers was the average particle size of the fillers.

The following information on the above rubbers is of interest in view of the difference in flexing properties :—

	Make A.	Make D.
Total fillers (per cent.)	30·2	36·5
Ash (per cent.)	22·2	22·5
Zinc oxide (per cent.)	3·0	3·6
Average grain size of filler (millimetres) ..	0·02	0·02–0·04
Maximum grain size of filler (millimetres) ..	0·08	0·15

There is considerable reason for believing that the superior flexing properties of the make A samples are due to the finer filler.

THE INFLUENCE OF BUTTERFAT

As the normal use of an inflation requires it to flex in the presence of butterfat, it was thought useful to determine the effect of this substance on flexing resistance. Three different makes of inflation of the same size were used. One of each pair of samples was immersed in dehydrated butterfat at 37°. The following percentages (by weight) of butterfat were absorbed. The flex test results are also set out :—

No.	Make.	Percentage Fat.	Length of Crack (Inches).
1	A	0	1·9
2	A	5·18	2·0
3	C	0	6·1
4	C	7·08	4·5
5	B	0	5·1
6	B	5·70	2·7

S = 1·28 ; X = 1·30.

The fat-treated samples show a slightly better flexing life than the controls, but the difference fails to reach significance (P = 5 per cent.). Provided that the position is not complicated by other factors which will be noted later, butterfat does not adversely effect the flexing properties of rubber at the concentrations tried.

THE TESTING OF RUBBER TUBING

As has been indicated earlier, milking-machine-claw tubing is subjected in use to rather drastic bending in addition to contact with warm milk. It is also handled under conditions where it may become greasy when farmers use greasy teat salves on the cows, and it is liable to be knocked on hard surfaces. Rubber for such work must be resistant to fat absorption and resist bending and knocking. Fat-absorption tests are carried out as in the case of inflation rubber. One-half inch lengths of tube are cut in the lathe and immersed in dehydrated butterfat at 45° C. Resistance to bending has been determined with the following apparatus.

The tube-testing machine is a device which makes possible the examination of the behaviour of rubber tubing when continuously bent through a definite angle at a definite rate. Essentially it consists of an arm to which suitable nipples may be connected and which swings through any desired angle with respect to a fixed platform carrying a second set of nipples. The centre about which the moving arm swings is in line with the middle of the sections of tubing under test. At present the device is fitted for testing claw tubing and therefore employs teat-cup nipples as means of holding the samples.

The motion of the arm is obtained by the use of a reciprocating chain drive, provision being made for variation of the stroke of the driving-crank, thus altering the angle of swing. There is also provision made by the use of an adjustable " jockey " sprocket for alteration of the position of the arc swept out by the moving arm with respect to the samples, thus making possible accurate adjustment of the machine to ensure that the tube is bent exactly the same amount on either side of the zero position.

END-POINT DETERMINATION

One of the greatest difficulties with any such testing instrument is the exact determination of the point to be taken as the end of the useful life of the sample under test. After some consideration it was decided to take the end-point as the stage in the cracking of the rubber at which the equivalent of a $\frac{1}{32}$ in. hole appeared through the wall of the tube.

The timing of the test is carried out by the use of four small magnetic clocks which are fed by one impulse per minute of direct current at about 60 volts. The time base is a Venner synchronous motor operating a small four-contact rotary distributing switch at 1 revolution per minute. This switch supplies the four clocks in turn with the necessary current. The source of direct current is a radio-type transformer and rectifier feeding

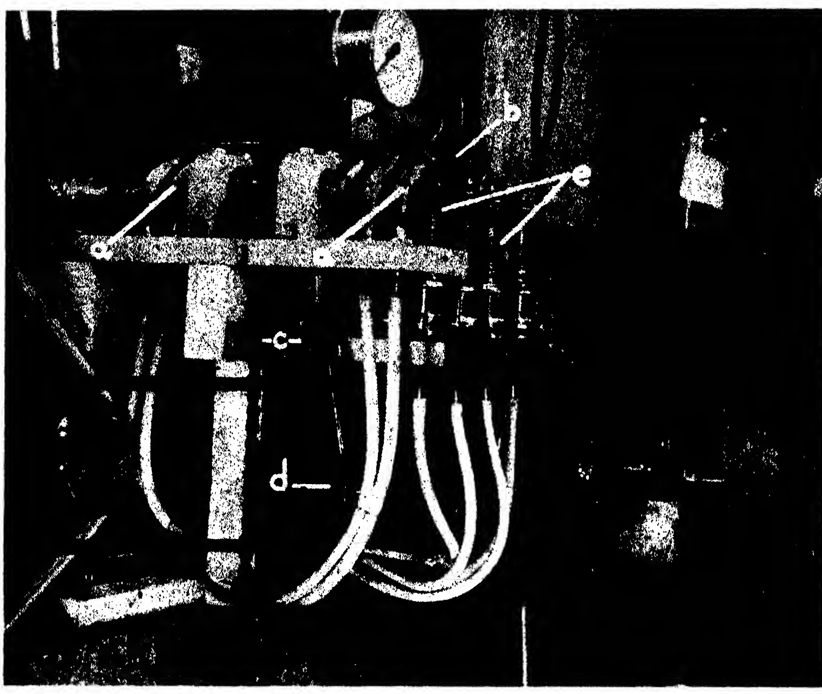


FIG. 1.—Rubber-tube-testing machine: (*a*) samples under test; (*b*) swinging arm; (*c*) driving chain; (*d*) adjusting sprocket; (*e*) vacuum-operated switches.

an 8 mfd. electrolytic condenser through a 6,250 ohms resistor, a bleeder resistance of 12,500 ohms to earth preventing excessive voltage building up at the distributor contacts. The advantage of this system lies in the fact that a high peak current is drawn from the condenser by the magnetic clocks, so ensuring positive action. Because of the high value of the resistance between the rectifier and the condenser, the maximum current drawn from the former is well below its safe maximum and no excessive current can be drawn for more than a brief period by the clock, so protecting the latter from overload.

Some trouble was experienced with chatter at the distributor contacts this being overcome by the use of a small braking mechanism.

In the circuit of each clock is a small switch which is opened by the movement of a spring-loaded diaphragm connected to the nipples holding the samples on the machine. The nipples are also connected to a 20 in. vacuum source via a $\frac{1}{32}$ in. hole. This means that when in operation all sample tubes are subjected to a 20 in. vacuum, which also holds down the diaphragms. The latter are adjusted so that as soon as a hole equivalent to $\frac{1}{32}$ in. develops in a sample the drop in vacuum resulting therefrom permits the diaphragm to move sufficiently to open the switch in the circuit of the clock timing the sample concerned. Owing to the nature of the test, any hole developing in a tube under test opens and closes as the tube bends. The switches are therefore arranged so that once open they remain so, regardless of the fact that the diaphragm will oscillate due to the alternate opening and closing of the cracks in the walls of the samples. Should the power fail, a no-voltage cut-out stops the motor driving the apparatus and the switches and cut-out have to be reset manually. The apparatus can be run continuously, thus saving much time.

The apparatus is illustrated by the accompanying photograph (Fig. 1).

The following are some results obtained on milking-machine-claw tubing (all of the following tests were carried out under the conditions indicated) :—

Bending rate	3,480 bends per hour.
Applied vacuum	20 in. of mercury.
Bending angle	$\pm$ 90°.
Length of sample	$2\frac{1}{4}$ in.
Distance between ends of nipples ..	$1\frac{1}{16}$ in.
Type of nipple	Teat-cup nipples from Thule-type cup.
Nature of test	Continuous at room temperature and in diffuse daylight during the day.

Results are expressed in the number of hours taken to develop the equivalent of a $\frac{1}{32}$ in. hole (the "life" of the sample).

Test 1

No.	Make.
1	Make A red claw tube.
2	Make A grey claw tube.
3	Make A red claw tube.
4	Make A grey claw tube.

Dimensions of Samples :—

	Cm.
Nos. 1 and 3—	
Average wall thickness	0·358
Average internal diameter	0·784
Nos. 2 and 4—	
Average wall thickness	0·374
Average internal diameter	0·788

No.	Life (Hours).	No.	Life (Hours).
1	70·4	3	80·8
2	158·0	4	136·0

The mean difference between pairs, 71·4.

Standard deviation, 22·9.

The results fail to reach significance with the number of samples involved. However, it is evident that there is a very considerable variation between samples made by one firm.

Test 2

This experiment was carried out to find the effect of butterfat on the bending resistance of rubber tubing.

Make A grey claw tubing was used for the test.

Samples 2 and 4 were immersed for seven hours in dehydrated butterfat at 45° C. The percentages of fat absorbed were 3·65 and 3·58 respectively. Samples 2 and 3 were untreated controls. The results of the bend test were as follows :—

No.	Life (Hours).	Percentage Fat.
1	52·12	0
2	50·05	3·65
3	52·05	0
4	42·80	3·58

$S = 5{\cdot}1;\ \overline{X} = 5{\cdot}7.$

The differences fail to reach significance.

Any effect which butterfat has is not very great. It is hoped to extend this work at some future date. Further results obtained with the bending tester are given in later sections of this paper.

THE MEASUREMENT OF PERMANENT SET

In the case of inflation rubber the measurement of permanent set is important, because the ability of a rubber to maintain tension under permanent fixed elongation is vital to the performance of a teat-cup with a "soft" inflation. The methods set out in the British Standard Methods of testing Vulcanized Rubber (903–1940) require the use of rings or dumbell strips of a prescribed size. This means that the test is applicable only to specially prepared pieces of rubber and not to the final article. The following is a description of a method which the writer has found to be very convenient and which can be applied to milking-machine inflations as such.

Samples

Ring-shaped samples $\frac{1}{8}$ in. wide are cut in the lathe from an inflation fitted over a wooden mandrel. When Emergency Standard inflations are used the rings are $\frac{7}{8}$ in. (or $\frac{13}{16}$ in.) by $\frac{3}{32}$ in. by $\frac{1}{8}$ in. The rings are dusted with French chalk and slipped over a smooth tapered steel cone so that the position of the ring is substantially normal to the axis of the cone. This gives the internal diameter. This determination is carried out again after the test, and care is taken to ensure that the ring is dropped on the cone the same side up as in the first determination.

Method and Conditions of Test

As inflations in use are elongated approximately the same amount regardless of type of rubber, a constant percentage elongation has been taken as the basis of our test. The B.S. test requires an elongation of 75 per cent. of the elongation at break. The following figures are the elongations at break for rubber supplied by New Zealand manufacturers :—

	Per Cent.		Per Cent.
1	760–800	4	630
2	800–840	5	710
3	685	Average	725

As 75 per cent. of 725 per cent. is 544 per cent., it was thought practical to use 500 per cent. as the fixed elongation to which all samples are subjected.

Periods of Stretch and Recovery

Following B.S. procedure, the sample is held at the required elongation for ten minutes, and allowed to rest for ten minutes on a glass plate before making the second determination of internal diameter.

To equalize the tension on the two sides of the stretched rings the holding pulleys are rotated.

The temperature is maintained within the range 21° C. ± 3° C.

Apparatus

The apparatus used has been devised specially for the above test. This is illustrated in the accompanying photograph (Fig. 2). Three sets of independent ½ in. pulleys (*a*) with knurled sides to facilitate turning are fixed as shown to the base board. The rings to be stretched fit over these pulleys and over the long detachable rod (*b*), which fits into sockets (*c*) on

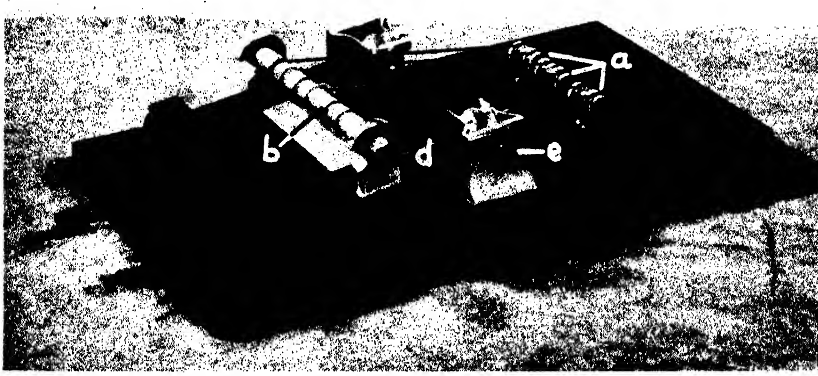


FIG. 2.

the main lever (*d*), which rotates about the bearings at (*e*). The grooves in (*b*) are ½ in. in diameter and the rod has knurled ends. Adjusting nuts at (*f*) permit the percentage elongation to be set accurately. When in the fully elongated position the lever is stopped so that the axis of the pulleys and the rod (*b*) are in line with the centres of the bearings (*e*). This means that the lever remains in position until the stress is removed.

Operation

The lever is moved to the position in which rod (*b*) comes against the independent pulleys. The rod is slipped from its sockets and the rings fitted over it and over the corresponding pulleys. The rod is then replaced and the rings elongated quickly, tension being made uniform on the rings by firstly rotating (*b*) and finally turning the independent pulleys until the two sides of each ring sound the same note when plucked. This ensures absolutely uniform tension.

The advantages of the device are quickness of operation, constancy of elongation, and cheapness.

All subsequent results are set out as the percentage increase in original internal diameter after the test. Unless otherwise specified, results are given as the average of two determinations.

The Permanent Set of Inflation Rubberware as sold in New Zealand

During a survey of dimensions of Emergency Standard rubberware, inflations were purchased at five different towns ranging from Whangarei to Invercargill, thus giving a well-mixed sample. Rings cut from these inflations were tested for permanent set and tensile strength, the latter determined as described later. The following are the results :—

No.	Make.	Percentage Permanent Set.	Deviation from Mean for given Make.	Tensile Strength (lb./sq. in.).	Deviation from Mean for given Make.
1	D ..	12·7	− 3·0	2,340	− 4
2	D ..	13·1	− 2·6	2,340	− 4
3	D ..	13·9	− 1·6	2,260	− 84
4	D ..	13·4	− 2·3	2,350	+ 6
5	D ..	16·9	+ 1·2	2,430	+ 86
6	D ..	13·4	− 2·3	..	..
7	D ..	18·8	+ 3·1	..	..
8	D ..	19·5	+ 3·8	..	..
9	D ..	15·3	− 0·4	..	..
10	D ..	20·3	+ 4·6	..	..
	Mean ..	15·7	S = 2·9	2,344	S = 60·2
1	A	18·0	+ 0·5	2,360	− 45
2	A	18·7	+ 1·2	2,510	+ 105
3	A .. .	18·5	+ 1·0	2,560	+ 155
4	A	18·6	+ 1·1	2,190	− 215
5	A	18·8	+ 1·5	..	..
6	A	15·8	− 1·7	..	..
7	A	16·0	− 1·5	..	..
8	A	15·2	− 2·3	..	..
	Mean ..	17·5	S = 1·5	2,405	S = 166·6
1	B	8·4	− 0·4	2,350	..
2	B	8·9	+ 0·1	2,070	..
3	B	9·5	+ 0·7	..	..
4	B	8·5	− 0·3	..	..
	Mean ..	8·8	S = 0·5	..	..
1	C	15·0	+ 3·7	2,070	..
2	C	15·2	+ 3·9	2,400	..
3	C	6·4	− 4·9	2,630	..
4	C	6·9	− 4·4	..	..
5	C	12·0	+ 0·7	..	..
6	C	12·0	+ 0·7	..	..
	Mean ..	11·3	S = 3·8	..	..

S = Standard deviation.

Deviations from mean and standard deviations have been calculated where there were four or more samples tested. The values for permanent set and tensile strength are in themselves valuable, but even more important is the standard deviation. This figure may be taken as an index of the "quality control" which the manufacturer can exercise. The smaller the figure, the more uniform the product.

THE INFLUENCE OF BUTTERFAT ON THE PHYSICAL PROPERTIES OF RUBBER

THE DETERMINATION OF BREAKING LOADS

Ring-shaped samples were fitted over $\frac{1}{2}$ in. pulleys on a machine operating under the conditions set out in B.S. 903–140, Testing of Vulcanized Rubber. The traverse rate of the moving pulley was 18 in. $\pm$ 3 in. per minute. The temperature was 21° C. $\pm$ 3° C. Four test pieces were taken and the average of the three highest results given.

Experiment 1

Three different types of rubber were used in this experiment. They were—(1) A soft carbon-black stock, make D; shore hardness, 43. (2) A soft rubber inflation, make C; shore hardness, 43. (3) A normal rubber inflation, make A; shore hardness, 49.

The samples (fifteen of each make) were soaked in butterfat at 45° C. for ten hours, after which three of each type were withdrawn and the amount of fat absorbed and tensile strength determined. The remainder of the samples were removed after twenty-two hours, and the tensile strengths (and in the case of two lots, the fat content) were determined at intervals with a view to ascertaining what changes, if any, occur when fat-treated rubber is left standing at room temperature. All determinations were carried out in triplicate, while all samples were rings which had the following average dimensions (in centimetres):—

Make D	0·242 by 0·312
Make C	0·231 by 0·332
Make A	0·239 by 0·304

The following are the results of the experiment:—

—	Make D.	Make C.	Make A.
Percentage fat absorption at 10 hours	23·19	24·09	16·21
Breaking loads of rings (in kilograms) after 10 hours in butterfat (average for three samples), (determined 30 minutes after removal from fat)	17·10	18·51	24·56
Original breaking load	27·50	24·47	25·95
Percentage change in breaking load	− 37·8	− 24·4	− 5·35
Percentage fat absorption at 22 hours	35·61	36·90	24·64
Breaking loads determined 0·75 hours after removal from fat	8·17	15·22	22·80
Percentage change in breaking load	− 70·6	− 37·8	− 12·1
Effect of standing at room temperature on samples containing butterfat—			
Average percentage fat for sets immersed in fat for 22 hours	35·67	36·97	24·68
Breaking load after 3·5 hours	5·72	12·47	17·76
Breaking load after 9·5 hours	9·59	13·96	22·49
Breaking load after 23·7 hours	8·93	14·96	22·68

The above results show, firstly, that a carbon-black stock loses tensile strength more rapidly than a clay stock when soaked in warm butterfat; secondly, that on standing at room temperature three quite different types of rubber show a drop, followed by a rise in tensile strength after removal from a bath of warm butterfat.

Experiment 2

(In this and subsequent experiments, unless otherwise specified, the rubber is used in the form of rings $\frac{7}{8}$ in. by $\frac{1}{8}$ in. by $\frac{3}{32}$ in.)

Four kinds of rubber were used in this test. They were—(1) A normal rubber, make D. (2) Make C, normal. (3) Make C, containing a small proportion of reclaim. (4) Make A, normal. Rings were soaked for two hours in dehydrated butterfat at 37° C. The following are the results:—

—	Breaking Load (Kilograms).		
	Untreated.	Fat-treated.	Percentage Change
1	22·17	24·18	+ 9·07
2	20·04	21·84	+ 8·98
3	18·51	17·34	− 6·32
4	22·17	23·76	+ 7·18

The only sample not showing an increase in tensile strength when treated with a small amount of butterfat is that containing reclaim.

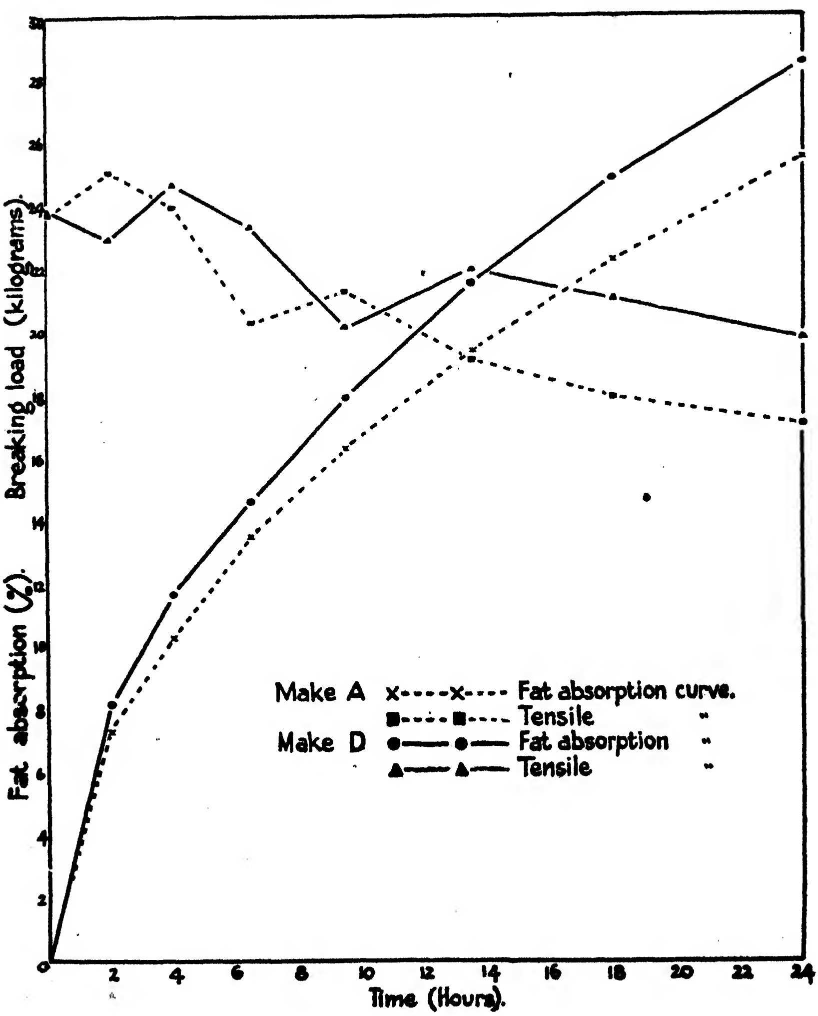


FIG. 3.

Experiment 3

This was carried out on two different makes of rubber (A and D). The rings used had the following dimensions (in centimetres) :—

Internal diameter	2·221
Width	0·316
Thickness—	
Make A	0·248
Make D	0·232

Forty-eight weighed rings (twenty-four of each make) were immersed in dehydrated butterfat at 45° C., lots of three being removed at intervals and the increase in weight (after the removal of excess fat) and the breaking load determined. The accompanying graphs set out the results (Fig. 3).

BUTTERFAT AS A FACTOR IN THE AGEING OF RUBBER

Because of its importance under field conditions, a fairly extensive examination has been made of the role of butterfat in the ageing of rubber. The preliminary experiment in this field was a test almost to destruction of a set of inflation rubber samples in a Geer rubber-ageing oven at 71° C. (in the dark).

The following are the conditions of the experiment :—

Experiment 1

Make	No.	Treatment.	Percentage Oil or Butterfat absorbed.
A	1	Stretched over 1¾ in. tinned brass ring	..
C	2		..
B	3		..
D	4		..
A (soft)	5		..
A	6	Immersed one hour in lubricating-oil at 70° C. and stretched over 1¾ in. rings	8·59
C	7		9·43
B	8		10·43
D	9		9·56
A (soft)	10		9·31
A	11	Immersed one hour in dehydrated butterfat at 70 C. and stretched over 1¾ in. rings	5·66
C	12		6·45
B	13		6·64
D	14		6·11
A (soft)	15		6·08

The samples treated as above were left in the Geer oven for fifty-six days—a very rigorous treatment. The following were the conditions of the samples :—

No.	Remarks.
1	Quite elastic and resistant to tear; no cracking—in good condition.
2	Pliable; easily torn—poor condition.
3	Hard and brittle; cracks on bending—extremely poor condition.
4	Quite elastic and resistant to tear—good condition.
5	Tears easily, cracks on bending—very poor condition.
6	Similar to No. 1.
7	Similar to No. 2.
8	Similar to No. 3, but a little more pliable.
9	Similar to No. 4.
10	Similar to No. 5, but does not crack on bending—poor condition.
11	Similar to No. 1.
12	Similar to No. 2.
13	Similar to No. 8.
14	Similar to No. 9, but fine surface cracks are developing.
15	Tears easily; but is more pliable than No. 10—poor condition.

The above test is equivalent to fourteen years of shelf ageing if we accept the views of Nellen and Sellers (*Ind. Eng. Chem.* [*Ind. Edn.*] *21*, 11, 1008). This is somewhat drastic, but the following points emerge from the test :—

(1) Neither butterfat nor mineral oil in the concentrations absorbed have any significant effect on the ageing of inflation rubber in the dark at 70° C. in an oven in which the air is constantly changed.

(2) Some rubbers are markedly superior to others in resistance to the Geer oven ageing test. Makes A and D put up an excellent performance.

Experiment 2

Ring-shaped samples of make D inflation rubber were taken and one-half of the samples smeared with butterfat. These were aged for six days in the Geer oven at 70° C. The results of the experiment are set out below :—

No.	Breaking Loads (Kilograms).		
	Controls.	After Six Days at 70° untreated.	After Six Days at 70° smeared with Butterfat.
1	19·44	19·44	20·01
2	21·87	21·24	20·34
3	21·84	21·06	18·39
4	22·02	20·55	19·56
Means ..	21·29	20·57	19·58

These differences are not significant.

THE EFFECT OF BUTTERFAT ON THE LIGHT-AGEING RESISTANCE OF RUBBER

Experiment 1

Ring samples ⅛ in. wide cut from standard inflations were used. All rings were stretched over glass plates giving approximately 200 per cent. elongation.

The following are the details of the tests carried out :—

Make of Inflation.—1, make B; 2, make A; 3, make C; 4, make D carbon black; 5, make D.

Group 1.—Controls. The unstretched rings in this group were left exposed to diffuse daylight indoors at room temperature.

Group 2.—The rings in this case were immersed in butterfat for two hours at 45° C. before being stretched on a glass plate. They were exposed to diffuse daylight at room temperature.

Group 3.—Similar to group 1, but exposed to the radiation of an enclosed carbon arc lamp as set out below.

Group 4.—Similar to group 2, but exposed to radiation from the carbon arc lamp.

The experiment lasted for a period of eleven weeks, the arc lamp being operated during the day for short intervals throughout the period.

The arc lamp operated under the following conditions :—

Capacity	1·28 kilowatts.
Total power consumed during experiment ..	116·10 kwh.
Distance of samples from lamp	10 in.
Temperature of samples	60° approximately.

The tensile strengths of the samples from the experiment are set out below. Four samples of each type are used, the following readings being averages for the three highest breaking loads of the four measured :—

Make.	Breaking Loads (Kilograms).			
	Group 1.	Group 2.	Group 3.	Group 4.
B	21·66	20·15	3·83	0·68
A	23·00	20·97	7·72	4·60
C	20·81	20·71	9·72	1·33
D (carbon black) ..	24·18	24·62	12·05	4·60
D	18·84	18·51	5·03	2·59*

* Average of two samples, the remaining two having broken during removal from the glass plates.

Notes on the Appearance of Samples :—

Make.	Incidence of Surface Checking.			
	Group 1.	Group 2.	Group 3.	Group 4.
B	—	+	—	++++
A	—	++	—	++
C	—	+	—	++++
D (carbon black) ..	—	—	—	—
D	—	++++	—	+++

+ = surface checking just evident; ++ = distinct checking; +++ = bad checking; ++++ = very bad checking.

The accompanying photographs (Fig. 4) illustrate the results of the experiment.

This experiment indicates, firstly, that the primary ageing factor associated with the arc lamp was the heating effect, though the influence of butterfat is very much in evidence. The striking difference between different rubbers in diffuse indoor light is further investigated in the following experiment. Carbon black, as is to be expected due to the screening effect of this pigment, reduces the tendency of a rubber stock to age under the influence of light.

Experiment 2

In this experiment an examination was made of the influence of butterfat on the surface of rubber. The effects of diffuse indoor lighting were compared with those of ½-watt lighting and daylight, and the influence of a commonly used anti-oxidant applied to the surface of the rubber was examined. Two kinds of rubber were used—namely, make C normal stock and make D normal stock with a smooth finish. The latter was used for the experiment on the change in the surface structure due to fat, as its smooth surface rendered it satisfactory for photomicrography. The usual ⅛ in. by $\frac{3}{32}$ in. by ⅞ in. rings were used for the experiment and one-half of each ring

was smeared with butterfat. The rings were stretched over glass plates giving an elongation of 200 per cent. All tests were done in duplicate.

The details of the experiment are:—

Group 1.—Exposed to diffuse light in laboratory at room temperature.

Group 2.—The same as group 1, but the fat-covered portion was also brushed with saturated solution of phenylbetanaphthylamine (a widely used antioxidant) in ethyl ether.

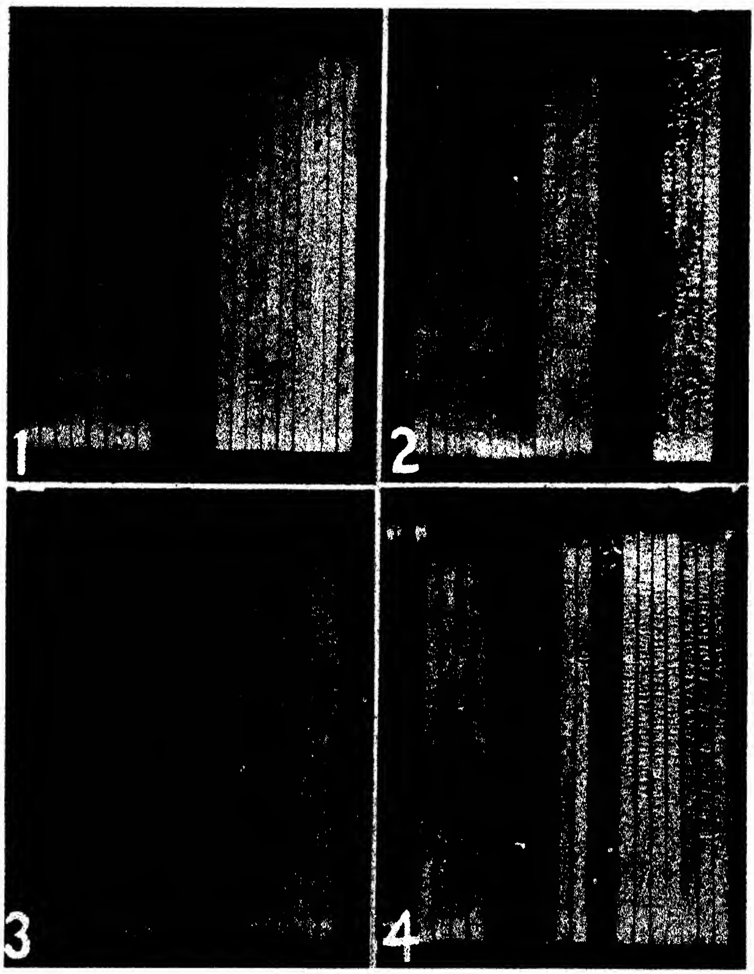


FIG. 4.

Key to photographs (each make was originally represented by four rings):—

MAKES IN ORDER FROM LEFT

(1) Make C; make A; make D, carbon black; make D; make B.
(2) Make B; make A; make C; make D, carbon black; make D.
(3) Make B; make D; make D, carbon black; make A; make C.
(4) Make A; make D, carbon black; make D; make C; make B.

Group 3.—The rings in this case were exposed to the light from a 500-watt lamp at a distance of 14 in. A fan kept the samples cool.

Group 4.—A single ring (smooth rubber, make D) was treated as above with fat and exposed out of doors in a quartz tube.

Group 5.—The rings in this case were kept in the dark at room temperature.

At the end of the experiment the breaking loads of the samples were determined, the figure obtained being, of course, due to the weaker half of the ring.

The results of the experiment are as follows:—

CHANGES IN TENSILE STRENGTH

Group.	Make.	Breaking Load (Average). (Kilograms).	Duration of Exposure to Light.
1	D (smooth) ..	17·60	40 days (12th August to 21st September).
	C	23·21	,,
2	D (smooth) ..	18·27	,,
	C	22·98	,,
3	D (smooth) ..	18·98	360 hours.
	C	17·19	,,
4	D (smooth) ..	8·24	Total light, 40 days; bright sunshine, 195 hours.
5	D (smooth) ..	21·25	0.
	C	21·17	0.

Changes in Surface Structure.—The accompanying photomicrographs (Fig. 5) demonstrate the influence of butterfat on the surface ageing of rubber. The lower sample (Fig. 5—1, 2, and 3) is treated with butterfat. The linear magnification = 10:—

1 .. .. The fat-treated sample is badly cracked, while the control shows no change.

2 .. .. The cracking is not quite as extensive over the whole sample as in No. 1, but is still bad in the case of the fat-treated sample.

3 .. .. Surface checking is in evidence in both cases, but is much more marked in the case of the fat-treated sample. Some of this checking is probably due to local heating which was not adequately kept down by the fan.

4 .. .. This is the fat-treated section of the ring exposed to daylight in a quartz tube. This is extremely badly perished.

5 .. .. This is the same rubber sample photographed at the end untreated with butterfat. Fine surface checking is in evidence, but it is quite different from the cracking of No. 4.

6 .. .. The two surfaces shown in this photograph show no detectable difference. These were kept in the dark throughout the experiment.

This experiment shows that a surface layer of butterfat on rubber accelerates the influence of light as an ageing factor but has no significant effect in the dark. Wave-lengths passing window glass are quite effective, though the full range of sunlight is much more destructive in its effects.

Experiment 3

Cleaning methods have been proposed (*N.Z. J. Agr.*, Sept. and Dec., 1943) for the removal of butterfat from rubber. The effect of the caustic-soda methods on light-ageing resistance was therefore investigated. In addition, the effect of acetone extraction was examined.

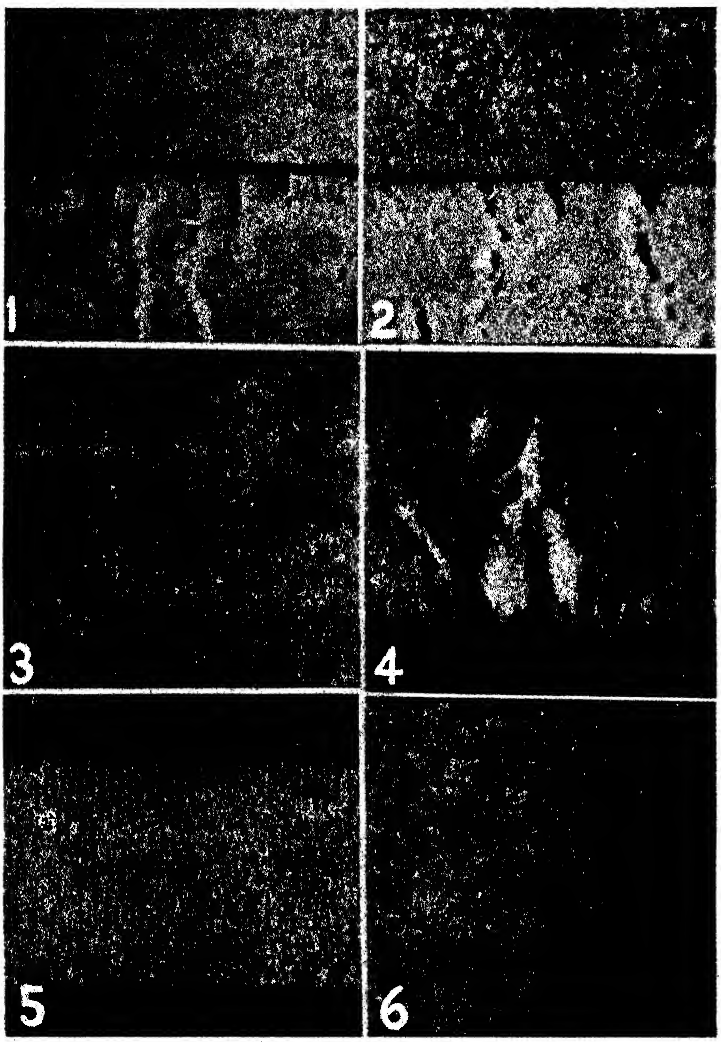


FIG. 5.

All samples were of make D rubber cut into $\frac{1}{8}$ in. rings, which were stretched to an elongation of about 200 per cent. on glass plates, the rings being turned so that the smooth surface (normally inner) was outside.

Twelve samples were taken and subjected to the following treatments:—

A. Immersed in butterfat at 45° for three hours. Weighed before and after—

1, 2 } Boiled in 5 per cent. caustic soda four hours and weighed.

3, 4 } Extracted in soxhlet apparatus with acetone for two hours. Weighed before and after.

5, 6 } Not treated subsequent to fat immersion.

B. 7–12. Not treated with fat—

7, 8 } Similar to Nos. 1 and 2.

9, 10 } Similar to Nos. 3 and 4.

11, 12 } Similar to Nos. 5 and 6.

Weights of Samples at beginning of Experiment:—

	g.		g.
1	0·6500	7	0·7065
2	0·7058	8	0·6958
3	0·7030	9	0·7133
4	0·6602	10	0·7036
5	0·6417	11	0·7053
6	0·6613	12	0·6976

Group A: *Fat absorbed*:—

No.	Weights after Immersions in Fat for Three Hours.	Percentage Fat absorbed.
	g.	
1	0·7235	11·31
2	0·7819	10·79
3	0·7792	10·85
4	0·7332	11·06
5	0·7137	11·23
6	0·7342	11·03

No.	Weights after Boiling Four Hours in 5 per Cent. NaOH.	Percentage Change with respect to Original Weight.
	g.	
1	0·6570	+ 1·076
2	0·7137	+ 1·120
7	0·6955	− 1·56
8	0·6859	− 1·42

No.	Weights after Two Hours' Extraction with Acetone in Soxhlet Apparatus.	Percentage Change with respect to Original Weight.
	g.	
3	0·6901	+ 1·835
4	0·6472	+ 1·968
9	0·7045	− 1·234
10	0·6947	− 1·265

Method of Exposure to Light.—The samples were placed at an angle of 45° in a window facing north-west just behind a pane of ordinary window glass and just above a ventilator so that a constant stream of fresh air passed the rubber, thus minimizing any possible (but unlikely) effects due to the atmosphere in the laboratory. All even-numbered samples were exposed as set out, while odd numbers were put in the dark-room (which, it should be noted, is not well ventilated). After exposure for forty days the samples were weighed, with the following results :—

No.	Kept in Dark.	Percentage Change with respect to Weight before Exposure.
	g.	
1	0·6586	+ 0·24
3	0·7015	+ 1·65
5	0·7149	− 0·17
7	0·6948	− 0·10
9	0·6946	− 1·41
11	0·7042	− 0·16

No.	Exposed to Light.	Percentage Change with respect to Weight before Exposure.
	g.	
2	0·7215	+ 1·09
4	0·6583	+ 1·71
6	0·7418	+ 1·04
8	0·6901	+ 0·61
10	0·6952	+ 0·07
12	0·7020	+ 0·63

NOTE.—In the case of Nos. 2, 4, 6, 8, and 10 a small amount of rubber was left adhering to the glass plate when the ring was removed. The above percentages for these samples are therefore slightly low.

There is a significant increase in the weight of the exposed samples, This is probably due to the absorption of oxygen. The increase is also greater in the case of the fat-treated samples than for the rest. A further important point is the fact that the acetone-extracted samples treated with butterfat, 3 and 4, showed a marked increase in weight despite the fact that the former was kept in the dark. Acetone, in dissolving out the natural and artificial anti-oxidants in the rubber, has accelerated the oxidation process. Of very great importance is the fact that this oxidation after acetone extraction proceeded almost as fast in the dark as in the light. However, when acetone-extracted samples are not treated with butterfat the dark sample decreased in weight while that exposed to light did not show significant increase.

Changes in Surface Structure of Samples.—The accompanying photomicrographs (Fig. 6A, B, and C) (linear magnification = 14×) show the changes in the surface of the samples described above. In the case of those exposed to light two photographs were taken, one of the side exposed to sunlight through the window pane, the other of the side exposed to the indirect diffuse light of the laboratory :—

1	No change in the surface.
2 (front)	Badly cracked. Deep fissures appear which almost sever the sample.
2 (rear)	Surface is covered with small cracks and has a spongy appearance.

3 ..	.. No change in surface.
4 (front) ..	.. No change.
4 (rear) ..	.. Cracks similar to No. 2 (rear), but slightly more frequent.
5 ..	.. No change.

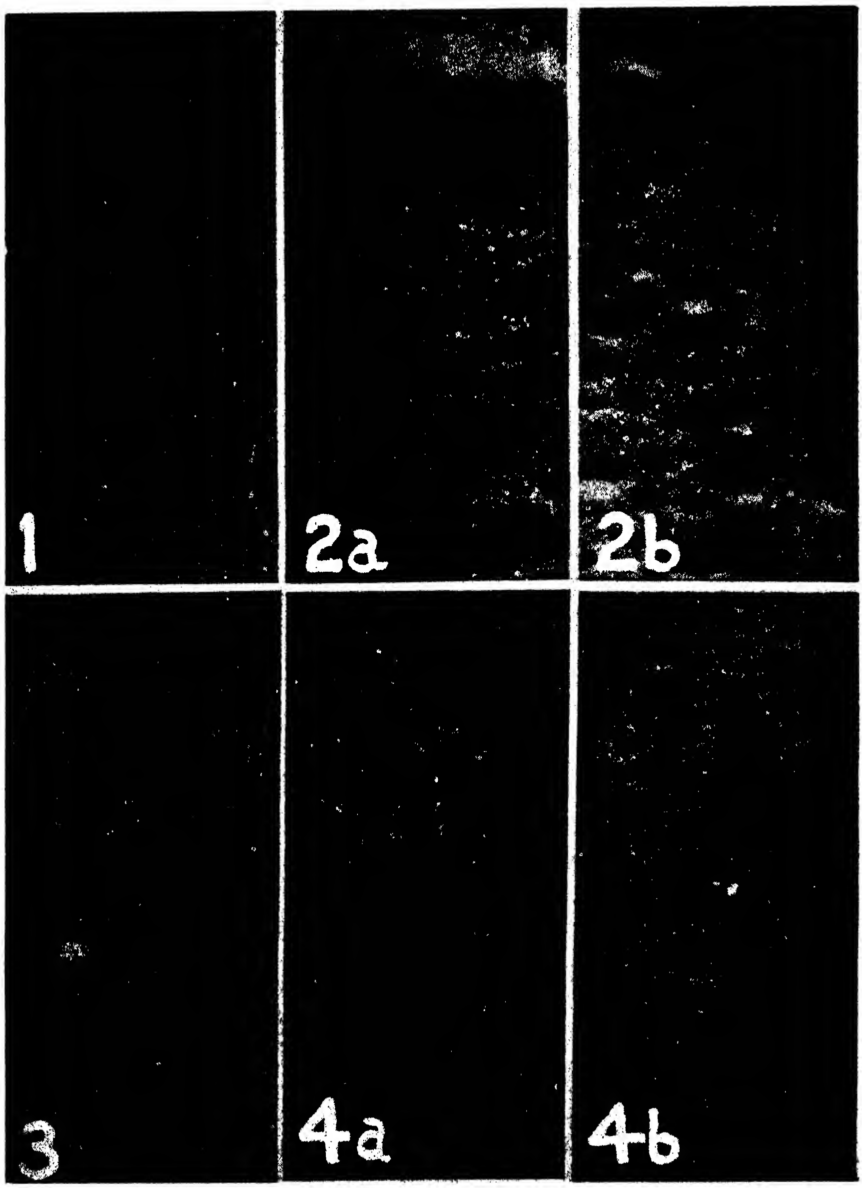


FIG. 6A.

6 (front) ..	.. Cracks appear at intervals over the length exposed to light. These cracks do not extend as deeply as those in No. 4 (front).
6 (rear) ..	.. Again there are many small cracks which, strangely enough, rarely effect the edges in this case—*cf.* No. 2 (rear).
7 ..	.. No change.

8 (front) ..	.. Only a few narrow cracks appear, but the surface has a rough appearance.
8 (rear) ..	.. Fine cracks appear in great numbers. The cracks are smaller than the previous rear samples.
9 ..	.. No change.

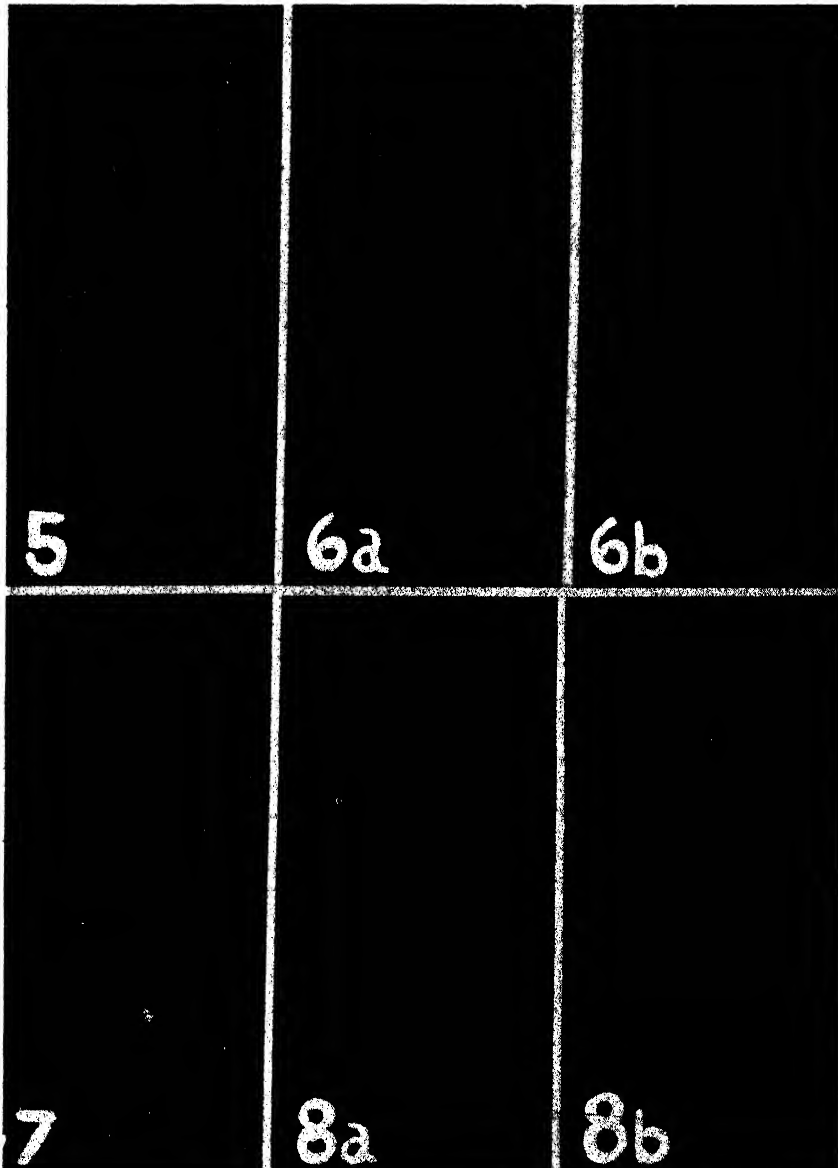


FIG. 6B.

10 (front) ..	.. Slight roughening of the surface.
10 (rear) ..	.. Fine spongy cracks appear all over the surface.
11 ..	.. No change.
12 (front) ..	.. Very slight roughening of surface.
12 (rear) ..	.. Spongy appearance and fine cracks all over the surface.

Discussion on Surface Changes.—It should be noted that samples exposed to direct light show a darkening in colour except Nos. 4 and 10. The sides exposed to indirect light are nearly normal in colour except Nos. 2 and 10, which show a distinct bloom.

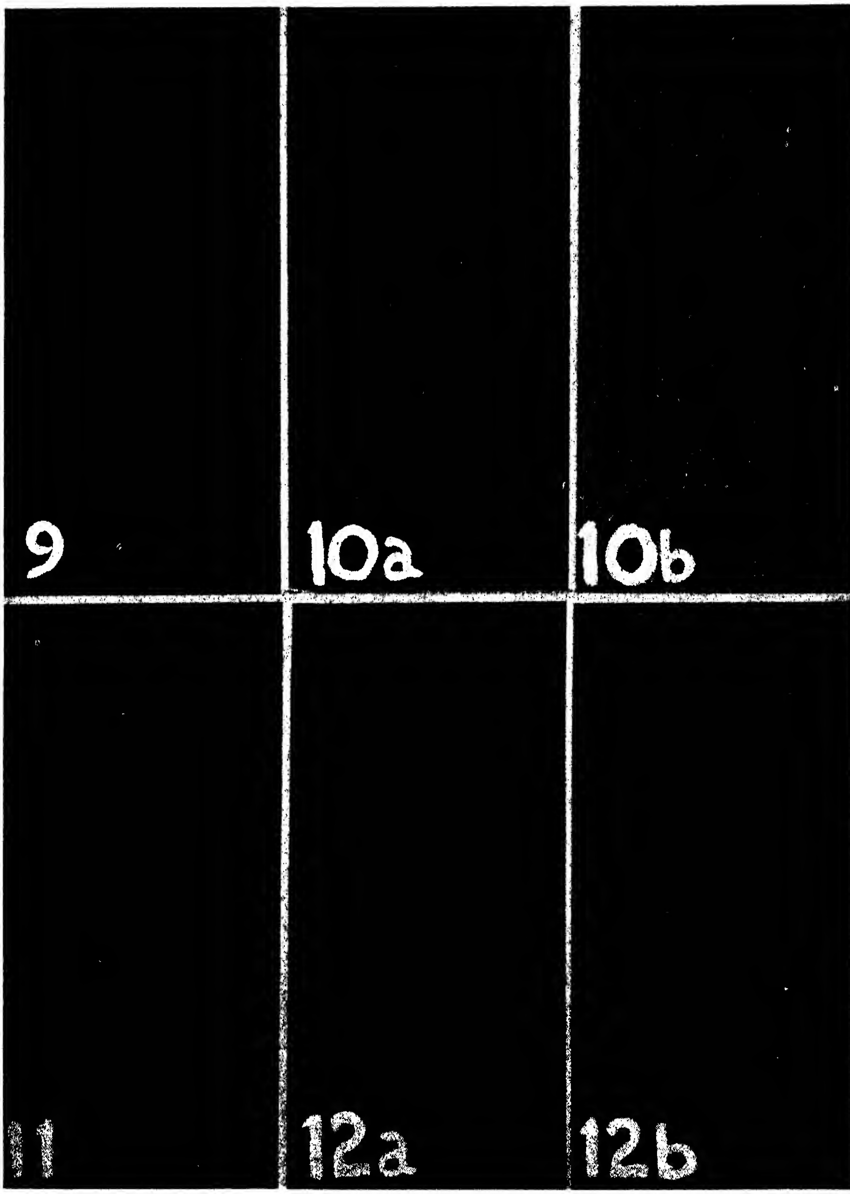


FIG. 6c.

The following are the main points emerging from the above experiments :—

(1) There is no noticeable effect in the rate of ageing of rubber stretched to 200 per cent. elongation if treated as set out above but kept in the dark :

(2) Samples treated with fat and subsequently boiled with caustic soda show a definite improvement in light-ageing properties over those treated with fat but not boiled in caustic soda :
(3) Samples treated with fat and subsequently extracted with acetone age in direct light as well as those not treated with fat but extracted with acetone. In diffuse light the fat-treated sample does not age as well as the sample not soaked in fat :
(4) Where the treatment is simple immersion in fat there is a definite reduction in light-ageing resistance over the untreated sample in direct light, but in diffuse light a different type of cracking is produced :
(5) Treatment with caustic soda somewhat reduces resistance to light ageing in direct light, but does not affect ageing in diffuse light :
(6) Acetone extraction reduces ageing resistance in direct light slightly by causing a surface roughening. In diffuse light there is no significant difference :
(7) Diffuse light (+ much ventilation ?) causes a different type of surface cracking from that produced by direct light. In some cases (caustic-soda extraction ; acetone extraction with and without butterfat ; and with untreated rubber) this ageing is worse than that caused by direct light. Whereas some samples showed no surface cracking in direct light (acetone extracted with and without butterfat and untreated sample in direct light), all showed marked cracking in diffuse light.

This latter point is difficult to explain. Two points should, however, be noted : (1) The diffuse-light samples were in a constant current of fresh air ; (2) the samples in direct light showed a darkening effect. It is possible that wave-lengths present in direct light promptly cause oxidation of the antioxidant to a dark-coloured compound in the surface layer which protects the lower layers of rubber from further light penetration.

Summary.—The above results may best be summarized by stating that, while butterfat accelerates light ageing, extraction with acetone or with caustic soda may be used to remove the butterfat without very seriously reducing the light-ageing resistance of the rubber.

Experiment 4

The above experiment was extended by examining the effect on the flexing resistance of the treatments there applied to rubber.

Samples of two makes of rubber (A and D) were taken and treated as indicated below.

They were then subjected to a flexing test, with the results given in the table :—

No.	Make.	Treatment.	Flex-test Results : Length of Cracks (Inches).
1	A	Boiled in acetone for two hours	4·7
2	D		4·7
3	A		4·7
4	D		3·5
5	A	Boiled in 5 per cent. caustic-soda solution for five hours	3·0
6	D		0·8
7	A		1·0
8	D		2·7
9	A	Controls	1·0
10	D		1·3
11	A		3·1
12	D		0·0

The mean difference between the acetone-treated samples and controls ($\overline{X}$) is 3·1, while the standard deviation of the differences between pairs, (S) = 0·95. The difference between the groups is highly significant, P = 1 per cent. In the case of the caustic-soda-treated samples, we find $\overline{X}$ = 0·6, S = 1·7. The differences are not significant. We may conclude that acetone treatment has a bad effect on the flex resistance of the rubber, while caustic soda shows practically no effect.

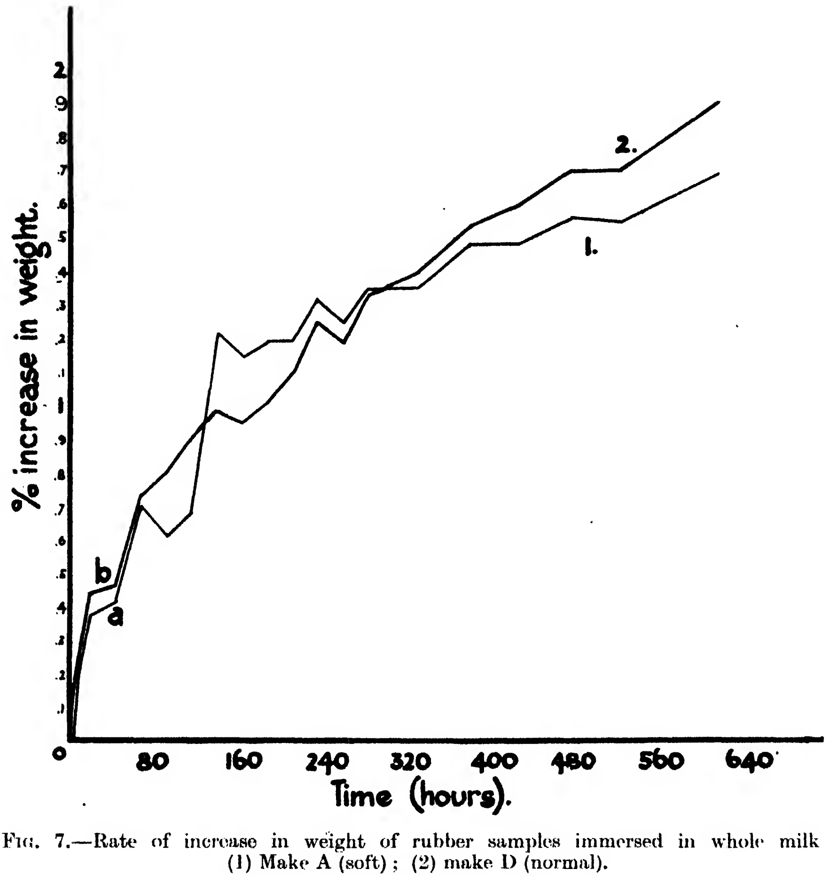


FIG. 7.—Rate of increase in weight of rubber samples immersed in whole milk: (1) Make A (soft); (2) make D (normal).

THE ABSORPTION OF MILK CONSTITUENTS BY RUBBER: THE INCREASE IN WEIGHT OF RUBBER IMMERSED IN MILK

The rate of absorption of milk constituents was observed by using duplicate samples of rubber in the form of rings $\frac{1}{8}$ in. wide cut from inflations. These were suspended in milk on a glass frame which moved gently up and down in the liquid, so preventing the separating-out of the cream. The frame passed through a gland in a lid covering the vessel containing the milk so that there was no evaporation. In order to prevent decomposition 1 per cent. of boric acid and 0·001 per cent. of acriflavine were added, the milk being changed every three days. The fat content of the milk was 2·9 ± 0·4 per cent. The temperature was maintained at 25° C.

The results are shown in the accompanying figure (Fig. 7).

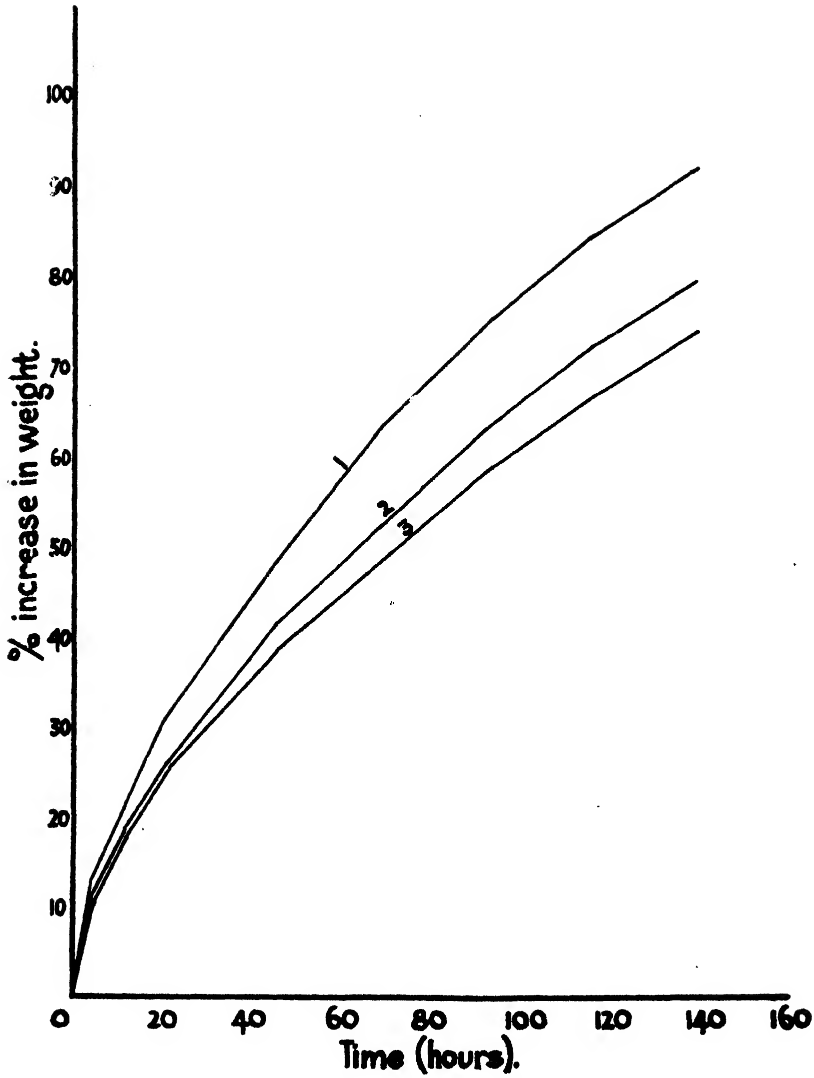


FIG. 8A.—Fat-absorption curves for a set of normal rubber samples.

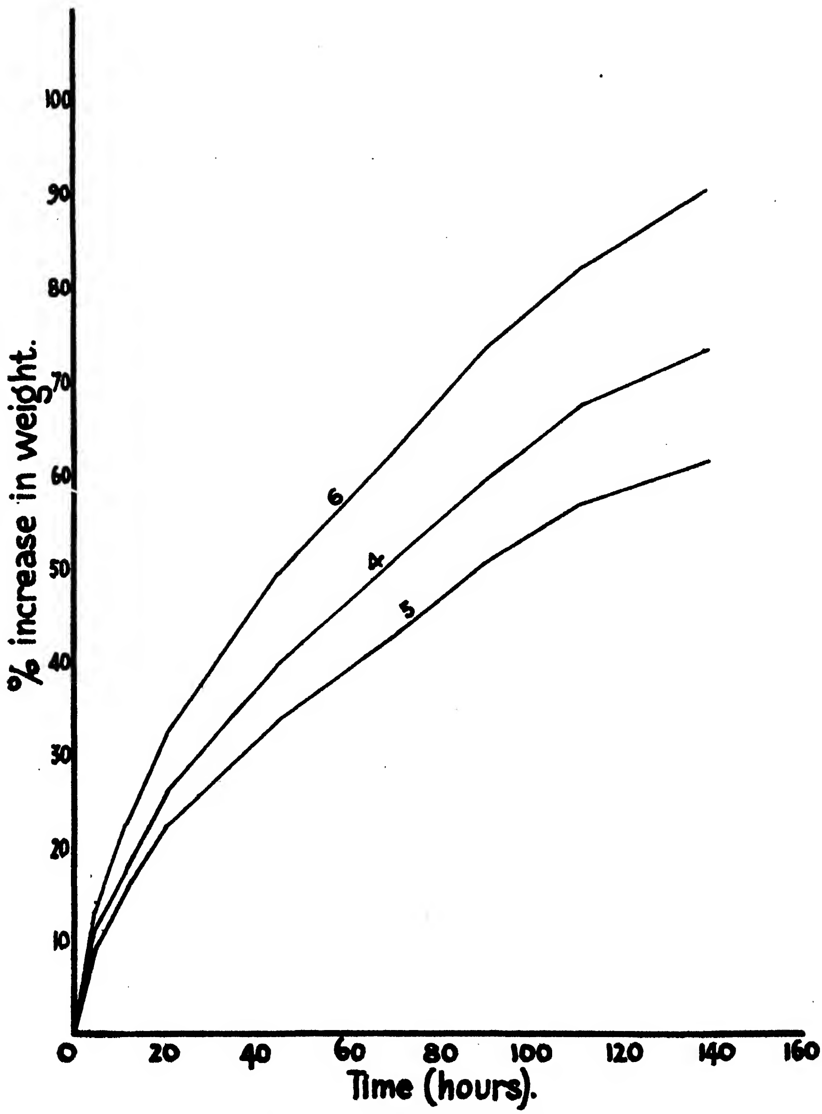


FIG. 8B.—Fat-absorption curves for a set of normal rubber samples.

ABSORPTION OF BUTTERFAT

A selection of inflation rubbers was tested for rate of absorption of dehydrated butterfat at 45° C. All samples were rings $\frac{1}{8}$ in. wide by $\frac{7}{64}$ in. thick and $\frac{7}{8}$ in. internal diameter. Figs. 8A and 8B give the absorption curves. For the sake of completeness the following table is given, setting out other properties of the rubbers tested:—

No.	Make and Type.	Percentage Pure Rubber.	Shore Hardness.	Tensile Strength (lb./sq. in.).	Elongation at Break (per Cent.).	Modulus (500 per Cent. Elongation).	Percentage Absorption of Butterfat at 45° C. after 100 Hours (W/W).	Percentage Increase in Weight in Milk after 200 hours (25° C., 2·9 per Cent. Fat).
1	Make C ..	78	47	2,260–2,420	800–840	..	78·2	..
2	Make A (soft) ..	..	..	..	..	..	66·8	1·25
3	Make B ..	71	43–48	2,160–2,560	760–800	..	61·3	..
4	Make D (normal)	67	44	2,200	685	900	62·4	1·12
5	Make D (hard grey)	58	50	1,800	630	1,100	53·0	..
6	Make D (soft)	78	40	1,950	710	550	76·8	..

(To be continued)

APPARATUS FOR THE MEASUREMENT OF THE RATE OF MILK-EJECTION IN THE DAIRY COW

By W. G. WHITTLESTON, Department of Agriculture, Animal Research Station, Wallaceville

[*Received for publication, 2nd October, 1944*]

IN the study of the influence of various factors on the milk-ejection reflex in the dairy cow it was necessary to have apparatus which would in no way affect the results of the experiments. There is considerable evidence that the reflex is a conditioned one which is extremely sensitive to environmental changes. The presence of strangers in the milking-shed, alteration of the sequence in shed routine, unusual sounds, &c., all disturb the normal milk-ejection process. It is necessary, therefore, when designing apparatus to fill the following conditions:—

(1) The apparatus should in no way alter the action of the normal milking-machine:

(2) The method should involve no alteration in shed routine such as long waiting-periods or the changing of buckets, &c.:

(3) The apparatus should be such that ordinary shed hands could operate it with no inconvenience.

Preliminary experiments with a weighing-machine indicated that to be satisfactory it would be expensive. A float-displacement method was examined, but again to be accurate and hygienic it required a rather costly mechanical set-up. The present method, though appearing complex, is relatively cheap, fool-proof, and positive in action. It has the advantage of being easily cleaned and is almost automatic.

The apparatus consists of a measuring unit situated in the cow-shed and a recording-unit placed outside of the shed at any convenient distance. For the work at present under way the measuring-unit is attached to a conventional mechanical milker. It could, however, be used for measuring the flow-rate of any liquid which has a high enough electrical conductivity.

THE MEASURING-UNIT. (Fig. 1)

This consists of a tinned copper cylinder (*a*) which connects to the teat-cups of the milking-machine via the inlet tube (*b*). A baffle arrangement (*c*) ensures that no froth will collect on the top of the milk as it rises in cylinder (*a*). The main cylinder is connected by a $1\frac{1}{4}$ in. tube (*d*), to the measuring-cylinder (*e*), which is made of bakelite 2 in. in diameter, and is connected at its top end to the top of the main cylinder by a tube (*g*). The measuring-cylinder is fitted with a spiral of fifty stainless-steel studs, and down its centre passes a nickelled electrode (*f*), which is connected to "earth." The unit is drained by a tube (*h*) so adjusted that when the

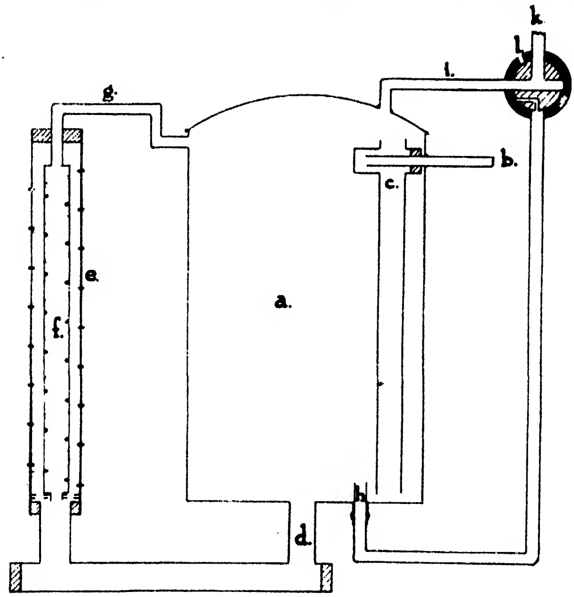


FIG. 1.

draining operation is complete at least one stud in the measuring-cylinder is covered with milk. A multi-port valve (*j*) is used to control the apparatus. In the position shown in the diagram (the working position) cylinders (*a*) and (*e*) are evacuated while (*h*) is closed, connection (*k*) being the lead to the milk-pipe of the milking-machine which supplies the vacuum. When a milking is completed the valve (*j*) is turned so that the vacuum connection to the cylinder (*i*) is opened to the air via the port at (*l*), while the draining-tube (*h*) is connected to (*k*), so draining the milk into the milk-pipe. This operation takes only a few minutes, and its completion is observed in a "sight glass" on the milk-pipe. In a second model of this unit two main cylinders (*a*) are used with a valve mechanism which cuts one of them out if necessary. This makes it possible to operate with two scales and so maintain the accuracy of the recorder when used on small yielding animals.

The position of the controlling valve (*j*) is indicated at the recorder by small lamps.

THE RECORDING UNIT

The circuit diagram of the recording unit is shown in Fig. 2.

COMPONENTS

T_1	240–5 volt transformer centre tapped and supplying 2·5 volts to he filament of V_1 and 5 volts to the primary of T_3, which supplies a secondary voltage of about 90.
T_2	240–12 volt centre tapped transformer supplying a small copper-oxide rectifier, O, which gives a rectified output operating the relay R_3 and the cut-out relay R_2.
T_3	5–90 volt transformer supplying high tension to the thyratron V_1.
T_4	240–5 volt centre tapped transformer supplying filament current to the rectifier V_2.
V_1	Type 2A4G thyratron.
V_2	Type 5Y3G rectifier connected as a half-wave rectifier with the plates in parallel.
M_1	Relay controlling the uniselector switch.
M_2	Cut-out relay.
M_3	Relay controlling the Venner synchronous motor V.
M_4	Driving coil of uniselector switch.
R_1	Centre tapped 200 ohm resistor.
R_2	100 ohm resistor.
R_3	Resistor adjusted to set drain on rectifier at safe maximum.
R_4	Variable resistor (5,000 ohm max.) to control bias voltage.
C_1, C_2, 3_3	0·5 m.f.d. tubular condensers.
C_4	16 μF. electrolytic condenser.
C_5	8 μF. electrolytic condenser.
C_6	1 μF. tubular condenser.
H	Filter choke.
V.S.	Vacuum operated switch.
S	Single pole double throw push button (zero resetting control for uniselector).
I	Rotary interruptor switch.
B	Bias battery.
U.S.	50 outlet automatic telephone uniselector switch.

Each of the uniselector contacts is connected to a stud contact in the milk-measuring cylinder via a twenty-five-pair lead-covered telephone cable. By this means the recorder is at a considerable distance from the measuring-unit.

The paper on which the record is made is fitted on to a bakelite drum directly coupled to the shaft of the uniselector switch.

ADJUSTMENTS

R_4 is set so that when the uniselector switch is connected to a contact covered with milk the thyratron just "fires." This ensures that when the contact is uncovered the bias rises due to an increase in resistance between the contact and earth and so stops the thyratron from conducting.

R_3 is adjusted so that the relatively steady current flowing through it charges condensers C_4 and C_5 enough to operate the uniselector positively. By this simple means the high voltage low current rectifier V_2 easily drives the low voltage higher current uniselector.

V.S. is a vacuum controlled switch situated below the tap on the milk dropper connecting the teat-cups to the measuring-unit. This switch brings the time base into operation as soon as the cups are put on the cow.

A small indicator lamp, not shown in the diagram, is used to indicate to the cowman that the cups may be put on.

ACTION

Let us suppose there is enough milk in the cylinder to come to the level of the draining-tube ((*h*), Fig. 1) which is so arranged that at least one contact is always submerged. Push button (S) is depressed, putting the switch into the lower position. Relay M_1 is held in the lower position by its spring. This means that the uniselector now moves until its wiper arm covers a closed contact which causes the thyratron to "fire," so pulling the relay contact into the upper position and stopping the uniselector. Releasing S results in the uniselector once more running, this time until it finds an open contact—the first one above the surface of the milk. The recording-drum is driven directly by the uniselector, while motor (V) drives the time-base,

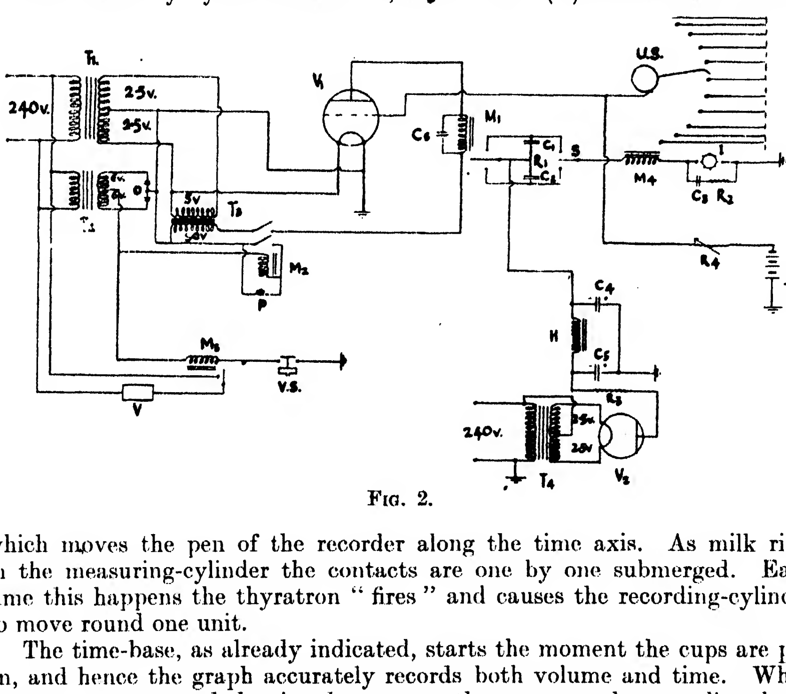


FIG. 2.

which moves the pen of the recorder along the time axis. As milk rises in the measuring-cylinder the contacts are one by one submerged. Each time this happens the thyratron "fires" and causes the recording-cylinder to move round one unit.

The time-base, as already indicated, starts the moment the cups are put on, and hence the graph accurately records both volume and time. When the cups are removed the time-base stops, the paper on the recording-drum is changed, and the uniselector set to zero by depressing S. The sequence of events is repeated on the next cow.

Relay M_2 and switch P are used to ensure that the thyratron is heated somewhat before a load is applied. When the power is turned off the plate circuit of V_1 is opened and cannot be closed until the press-button P is depressed.

(It should be noted that the curious arrangement in which the high tension voltage for V_1 is taken from a step-up transformer T_3 was employed because the transformer was available and could not be used for anything else.)

The time base is a simple screw driven by a Venner synchronous motor V. A half-nut rests on the screw and so drives the pen across the paper. The pen has to be reset to zero manually.

Calibration.—Volume, 1·36 cm. = 1 lb. of milk.
1 contact. = 0·235 lb. of milk.
Time : 1·268 cm. = 1 minute.

METHOD OF OPERATION

The following is the procedure when making milk-flow graphs. A sheet of paper is fitted to the machine and the pen put in the writing position. By means of a small switch an indicator lamp in the shed is turned on, letting the cowman know that the apparatus is ready to run. As soon as the cups are applied the time-base starts. The uniselector (set to search

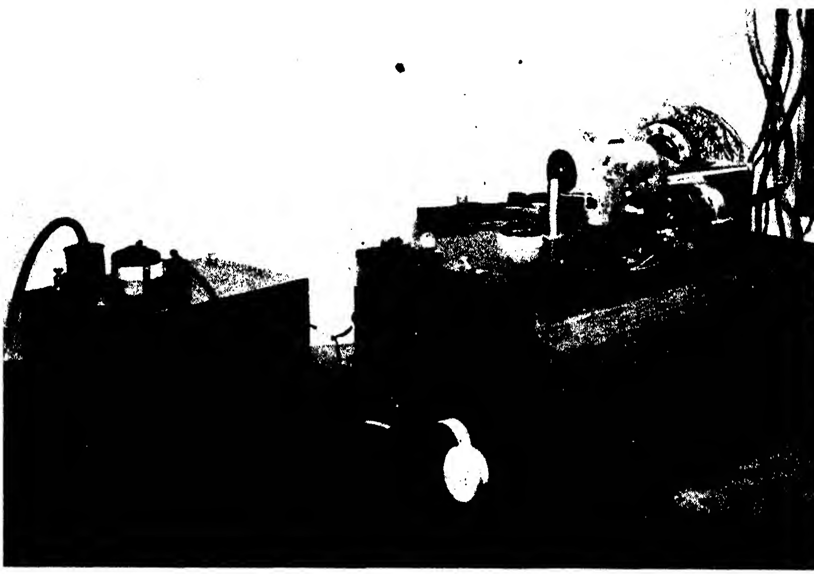


FIG. 3.

for open contacts) rotates the recording-drum as the milk rises in the measuring-cylinder. The cowman removes the cups at the end of milking, so stopping the time-base, and turns the control valve, which causes the main cylinder to drain into the milk-pipe. This operation is indicated at the recorder, whose operator switches the uniselector into the position in which it hunts for the first closed contact. This means that it runs right round, coming to rest on the lowest stud, which is always under milk. While another cow is being brought in and the cylinder drained, the paper on the recorder is changed and the time-base set to zero. When the control valve is turned to the " run " position the uniselector is switched back to the " operate " position, when it promptly seeks out the first open contact and stops. This ensures that the pen always starts at the real zero regardless of possible errors due to careless draining on the part of the cowman. The application of the cups starts the time-base and the cycle is repeated.

A general view of the recording unit is shown in Fig. 3.

Figure 4 shows four graphs as taken from the machine. These show the nature of the recording and, incidentally, the variation in milk-flow curves.

Work employing the above apparatus is being undertaken at present, and results of the experiments made possible by this new apparatus will be published from time to time.

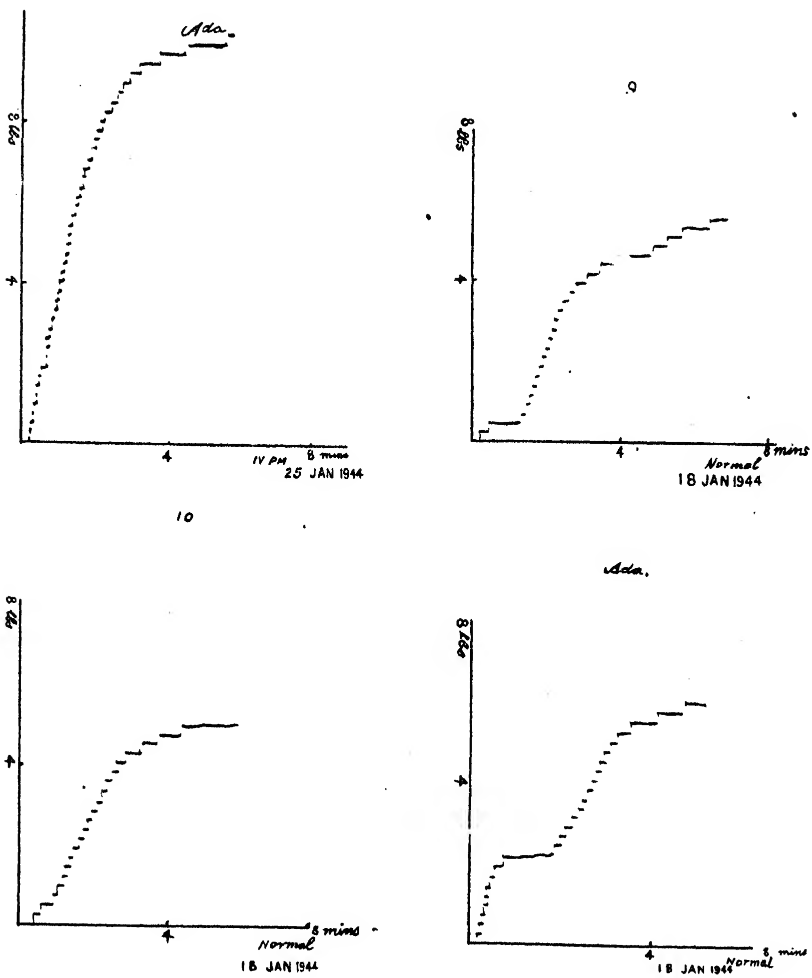


FIG. 4.

ACKNOWLEDGMENTS

The writer is greatly indebted to Mr. H. G. Sawtell, of this Laboratory, who did much of the constructional work, and to Mr. G. H. J. Underwood, of Messrs. Standard Telephones and Cables Pty., Ltd., who was very helpful in the search for suitable components for the above apparatus.

TECHNIQUES FOR SOIL FUNGUS STUDIES

By I. D. BLAIR, Canterbury Agricultural College

[*Received for publication, 28th September, 1944*]

Summary

Published literature relating to direct microscopic examination of organisms within soils has been reviewed.

An application of the Rossi-Cholodny glass slide technique has proved successful in providing a method for examining growth of the fungus *Rhizoctonia solani* Kühn in natural soil. Direct examination in tubes of soil has also been found possible.

The techniques are described, and photographic figures are presented illustrating some of the growth studies which may be developed using such techniques.

ATTRIBUTES of a soil environment in their relation to pathogenic fungi have generally been defined according to host-parasite studies. The physiography and meteorology of a soil " micro-habitat " obviously influence the activity of micro-populations, but these influences on a pathogen are usually correlated not with growth measurements of the organism *in situ*, but rather with some degree of parastic infection in a host-plant susceptible to attack by the particular soil inhabitant. Probably parasitism studies provide the easiest method of study, but it is desirable to ascertain something more also of the effect of soil conditions on the organisms themselves as well as on attendant diseases.

REVIEW OF LITERATURE

The first suggestion of a direct microscopic study of organisms as they occur in the soil seems to have been made by Conn (1917). His method essentially was to make a soil infusion in dilute gelatin, dry this on a slide, and stain for examination with phenolic rose bengal or erythrosin. Winogradsky (1924A, 1924B, 1925) discussed direct methods of studying bacteria in the soil, and in his studies employed a technique which was a modification of Conn's original methods. European investigators soon became interested in these methods, and further modifications were adopted. For instance, a technique for fixing and staining a measured portion of soil infusion on a slide was devised by Koffman (1928), and this enabled a determination to be made of the kinds of organisms present in soil samples. An even more direct procedure was offered by Rossi (1928), Rossi and Gesue (1930). In their studies a vertical face of soil was exposed and a glass slide placed against this surface. After removal and staining, the slide depicted micro-organisms as they actually occurred in the soil at any one time. This principle was pursued by Cholodny (1930), who perfected Rossi's technique, placing the slides in a specially devised holder in a shallow trench with one side of the slide held in position against the vertical face of the undisturbed soil. Cholodny's method differed essentially in that the slides were not removed immediately, but were allowed to remain in position for some time before the soil picture was fixed and stained.

This technique, which may be referred to as the Rossi-Cholodny method, as each worker was responsible independently for its development and application, has already been used in a varying manner of ways. It was used by Conn (1932), who proved that it was satisfactory in demonstrating a change in the microflora of the soil from fungi or actinomyces to bacteria or

vice versa. Eaton and King (1934) employed the method to ascertain the time of the year at which growth begins of the cotton root-rot fungus, *Phymatotrichum omnivorum*, and the depth to which the activity of this fungus may occur. Jensen (1934 1936) adopted the technique in a quantitative study of the occurrence of certain soil fungi by estimating the frequency of fungal hyphæ in 500 to 550 randomized microscopic fields on Rossi-Cholodny slides, and Garrett (1938), using a similar calculation as Jensen, showed that the slide method could demonstrate the decline of *Ophiobolus graminis* mycelium in relation to the percentage occurrence of other soil fungi. More recently Timonin (1940) placed slides in soil samples, and subsequent fixation of these revealed noticeable differences in the abundance of microbial accumulations in the rhizosphere compared with soil distant from the roots of those plants under study. Waksman (1932) refers to the method, stating that it may be used qualitatively to show micro-organisms which exist in the soil in active form, but he affirmed that it was not applicable to quantitative investigations. Since then, however, and as outlined in this review, Jensen, Garrett, and Timonin have all demonstrated quantitative effects from the use of this slide method.

The implications of much of this reviewed experimental work suggest that an application of the Rossi-Cholodny technique might be suitable in developing growth studies of some fungus organisms under natural soil conditions. Such work has been undertaken with results reported on by Blair (1942, 1943), but no descriptive account of the technique associated with these studies has as yet been published.

EXPERIMENTAL METHODS AND MATERIALS

The Organism.—Numbers of isolates of the fungus *Rhizoctonia solani* Kühn were obtained by standard isolation methods and maintained on potato dextrose agar slopes pending further study.

The Soil.—Investigations of the activities of the fungus were conducted in unsterilized field soil. From processes carried out by pure cultures of micro-organisms grown in sterile soil it is difficult to determine what actually does occur in normal soil, for not only is the nature and composition of the culture medium completely changed by sterilization of the soil, but the various antagonistic and associative influences which are active in normal soils are eliminated. Such differences between unsterilized and sterilized soil as a medium for fungus growth and activity have been emphasized by Waksman (1927), Flor (1940), Tervet (1937), Sanford (1939).

The soils used as the medium of fungus growth were sieved in the field, passing ¼ in. mesh, then thoroughly air dried under glass or over a steam boiler, crushed by a roller and passed through a 2 mm. sieve, ready for final use. The saturation capacity of all soils or soil mixtures was determined by the perforated-box method of Keen and Rackowski (1921). In growth studies glass tumblers, such as Garrett (1936) used in his *Ophiobolus* studies, were partly filled with a weighed quantity of the prepared soil, the water content of which was adjusted to any desired degree of the estimated saturation capacity. Where a low degree of moisture content was desired the weighed amounts of soil and water were mixed by hand in a container before being added to the tumblers. In this manner an even distribution of the limited amount of water was assured. On the other hand, where a high degree of soil saturation was required, the larger amounts of water could be added directly to the tumblers of soil, for the quantity of water at, say, 80 per cent. of saturation, was sufficient to ensure an even distribution of the water without previous mixing by hand. In any case

where the water content of the soil had to be adjusted the tumblers were left standing at least twelve hours after the addition of the water and before inoculation, to permit a natural and even distribution of soil moisture.

Arrangement of Slides and Soil Inoculation.—The glass slides used to provide the measure of *Rhizoctonia* growth through the soil were cleaned in solutions of hot acidulated potassium dichromate, followed by successive washings in alcohol, then water, before thorough drying. Four dry slides were placed vertically in the soil of each tumbler, arranged in the form of a hollow square as illustrated in Plate 1. With the slides in position and with water content adjusted to the desired degree of the saturation capacity, a piece of inoculum of *R. solani*, consisting of a 6 mm. disk of the organism taken from the periphery of a culture growing on a potato-dextrose agar plate, was placed in contact with the inner face of each slide, at a line marked on the slide ¼ in. below the level of the soil surface. After inoculation each tumbler was covered with ¼ in. mulch of sand, the water content of which

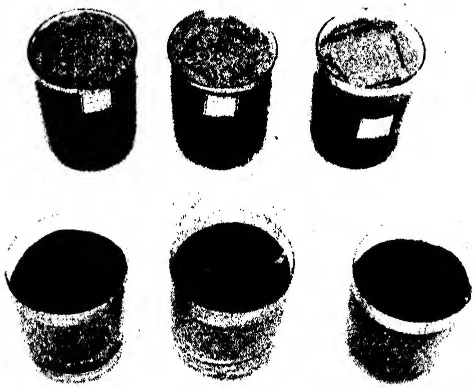


PLATE 1.—Vertical arrangement of glass slides in soil tumblers, used to measure the extent of growth of *R. solani* in soil.

Lower: L. to R.: Air dry sieved soil in tumbler; marked slides ready to be placed in position; slides in position with the water content of soil adjusted.

Upper: Tumblers with wet sand mulch during the course of a typical experiment designed to measure the growth of *R. Solani* through the soil.

was also adjusted to the same percentage of its saturation capacity as in the case of the soil. The tumblers or pots in any one experiment were randomized in their arrangement on a bench and left throughout at room temperature. Any losses in weight were adjusted by adding water at daily intervals, if necessary, to bring the tumbler weight back to the original. Distilled water was used throughout. For each treatment there were usually four tumblers each with four slides—*i.e.*, estimates of the mean results were made from the observations on twelve slides per treatment, and the statistical analyses of the replicate results indicate that this arrangement presented a high degree of accuracy.

Glass tumblers were used throughout investigations conducted in England. In Canada 4 in. baked-clay flower-pots were used, but the preparation and arrangement was exactly the same as described above.

In certain experiments a different arrangement was adopted. The slides, instead of being arranged vertically as shown in Plate 1, were placed horizontally in large glazed clay vitrolite crocks containing the soil. They were then arranged in radial fashion. This arrangement is illustrated in Plate 2. This method lent itself especially to studies of fungus growth at soil depths in excess of the dimensions of vertical glass slides. The slides were placed radially and fungus inoculations made first at the deepest level under study followed by a similar arrangement as the container was filled through the shallower levels. The organism was introduced as before at a marked point on the slide, ¼ in. beneath the surface. In either method it was determined by preliminary observations that as the fungus spread through the soil from the point of inoculation, hyphal threads also came in contact with, and moved along, the glass slides. It was believed that the extent of the growth of the mycelium along the slide was a valid indication of the extent of spread of the organism through the soil in the vicinity of the slide, the amount of growth being influenced by the particular soil conditions which were under investigation at the time.

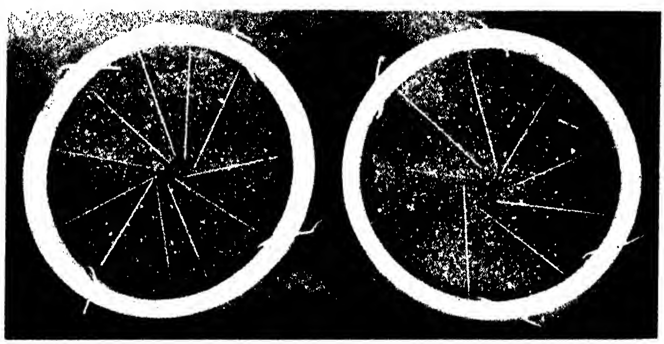


PLATE 2.—Radial-horizontal arrangement of glass slides, used to measure the extent of growth of *R. solani* in the soil.

Examination of the Slides.—At the conclusion of each experiment the slides were removed from the tumblers in such a manner that the central core of soil bounded by the slides remained intact. This central core was lifted from the tumbler after removal of the soil outside the boundaries enclosed by the group of slides. The method of removal is illustrated in Plate 3. The slides were then detached from the soil, air dried, fixed, and stained in a bath of steaming 5 per cent. erythrosin in 5 per cent. phenol, permitting an immersion of one minute. Excess stain was removed by quickly dipping the slides in a beaker of running water, before leaving them to dry. It was found, also, that a steaming 1 per cent. phenolic solution of Rose-Bengal stain was suitable for fixing and staining the slide picture, but the erythrosin stain was generally used for this purpose.

Depending upon the conditions of the experiments, and details of these have been published by the writer (*loc. cit.*), the fungus hyphæ were found to have moved along the slide and to have been fixed on the slide surface by the above treatment. Using a high- or low-power microscope objective, the course of the fungus along the slide could easily be followed and therefore measured right from the original mark of inoculation to the terminal extremity of mycelial growth (Plate 4). It is possible that movement through

the soil in the vicinity of the slides may not be entirely comparable with movement of the fungus through or between soil particles at some distance from the slides. In its movement through the soil the organism may be provided with a path of less resistance in the zone defined by the surface of the slide and the soil particles. Further, the measure of growth on the slide cannot be interpreted arbitrarily as the full extent of the growth distance in the soil, for the fungus would certainly ramify in all directions between soil particles, not only in the single plane of the surface of vertical or lateral slides.

These facts would not appear, however, to detract from the value of the method as an indication of the extent of growth under soil conditions. The value of the method also lies in the fact that it permits an examination of the organism in natural soil, under those conditions associated with what Kubiena (1938) refers to as the soil "micro-climate" or "micro-habitat." By the use of this slide method it seems that one is justified in interpreting the growth measurements as an indication of the influence of existing or adjusted soil conditions on the development of *R. solani*.

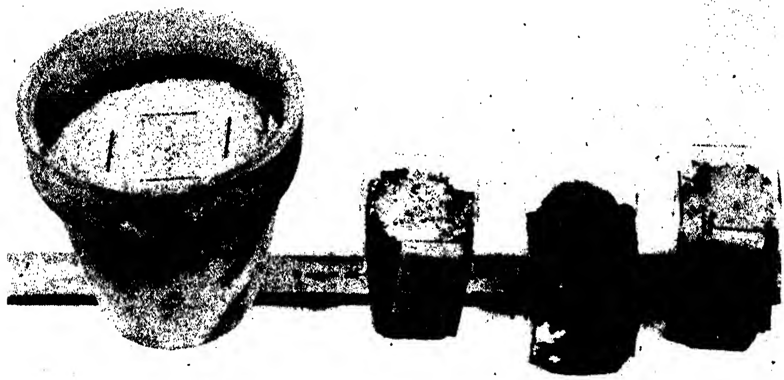


PLATE 3.—The method of removing slides from pots or tumblers, prior to fixing and staining.

The fact that unsterilized soil was used as the basic medium made it inevitable that the picture on the slide would also consist of, and in fact in many cases be dominated by, a profuse development of the other micro-flora of the soil; in addition to the hyphæ of *Rhizoctonia solani* spreading from the line of inoculation, many forms of bacteria, protozoa, actinomyces, and other fungal hyphæ and fruiting bodies could be discerned. This was to be expected, for it was for the purpose of securing such pictures of the micro-flora of the soil at any one time that this slide technique was applied by the early investigators whose work has already been reviewed. Nevertheless, in spite of the density of other micro-organisms, it was always possible to trace accurately the full extent of the growth of the inoculated fungus and to be able to distinguish between the hyphæ of the inoculated *Rhizoctonia* and those occasional hyphæ of this organism which had apparently developed from a spontaneous source in the non-sterilized soil. In the first place, the morphological characteristics of the mycelium of *Rhizoctonia solani*, as described by Duggar and Stewart (1901), were diagnostic even in the presence

of the other organisms. For instance, the young hyphæ branch at an acute angle from the parent hypha and subsequently lie parallel to it. A constriction usually occurs at the point of union, and a septum is almost invariably laid down a short distance from this point. The hyphal threads are usually thick in width, with dimensions ranging from 10–25 microns. With age the hyphæ lie more or less at a right angle to the main axis, showing less constriction at the points of origin. They deepen in colour to a yellow, then to a deep shining brown, and become more or less empty and granular. These " brown runner " hyphæ are a diagnostic feature. The mycelium is

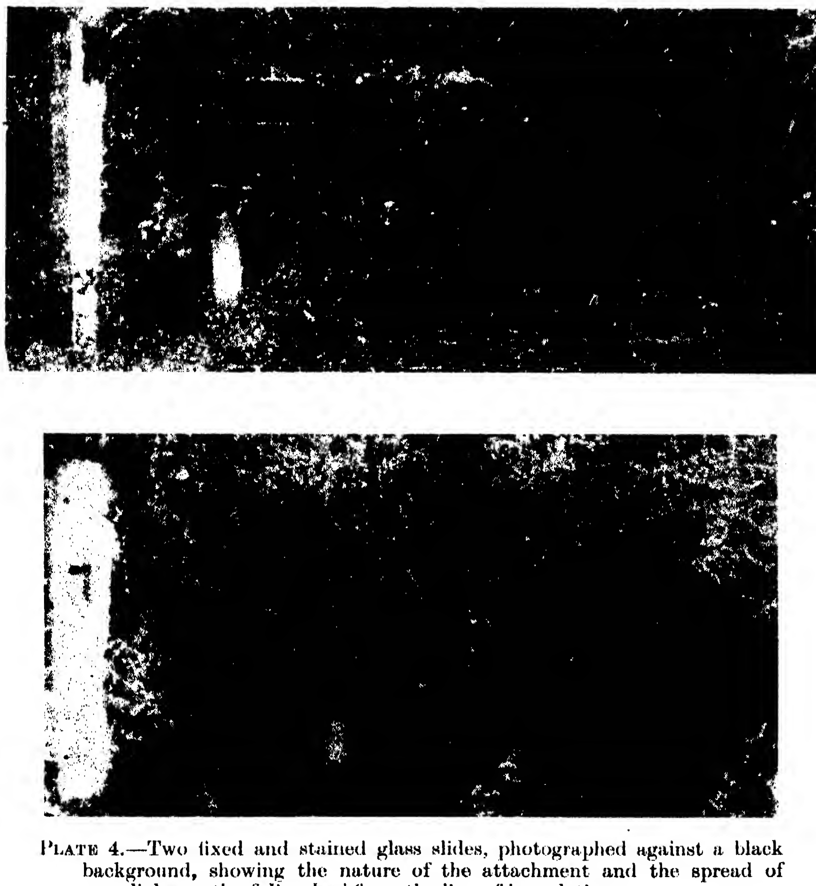


PLATE 4.—Two fixed and stained glass slides, photographed against a black background, showing the nature of the attachment and the spread of mycelial growth of *R. solani* from the line of inoculation.

also characterized by a very direct and straight habit of growth. Plates 5 and 6 depict typical microscopic fields of *R. solani* mycelium from such growth on slides as shown in Plate 4.

The check on the fact that the *Rhizoctonia* mycelium along the slide was from the original inoculation rather than from some source already in the soil before inoculation, lay in the degree of accuracy with which one could follow the mycelium under the microscope from the line of inoculation. Sometimes a break in the continuity of growth would be observed. If

such a break was small it seemed reasonable that any continuation of growth beyond the break was indeed a continuation of the same mycelium, especially if the plane and direction of growth were identical in each case. In no instance

PLATE 5.—A typical microscopic field of *R. solani* mycelium from such growth as shown on the slides in Plate 4. × 120.

did a slide exhibit the presence of *Rhizoctonia* of spontaneous soil origin which could not be distinguished from that originating from the introduced culture.

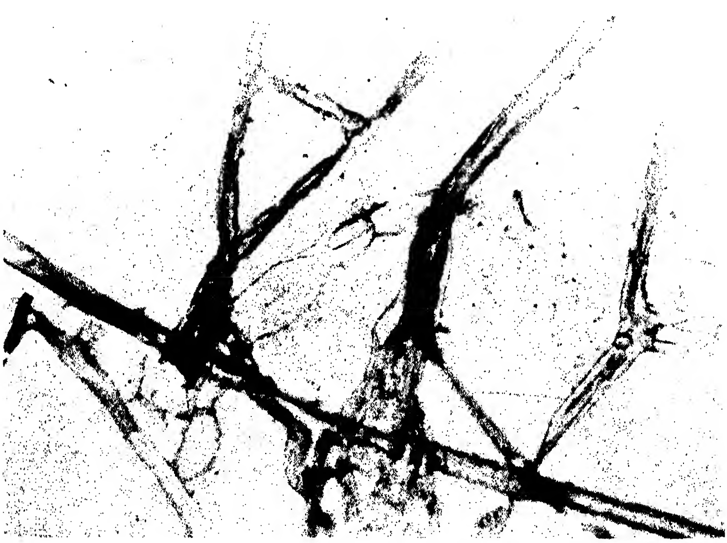


PLATE 6.—A typical microscopic field of *R. solani* mycelium from such growth as shown on slides in Plate 4. × 400.

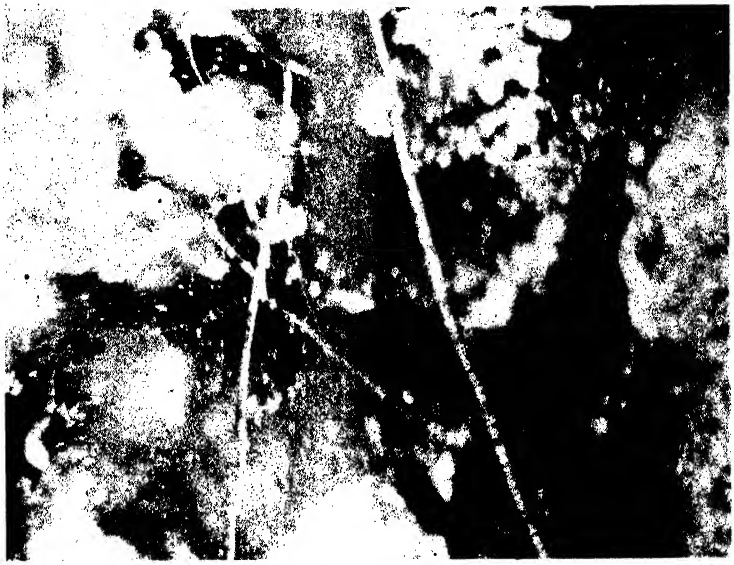


PLATE 7.—Runner hyphae of *R. solani* growing through soil in glass tubes. × 75.

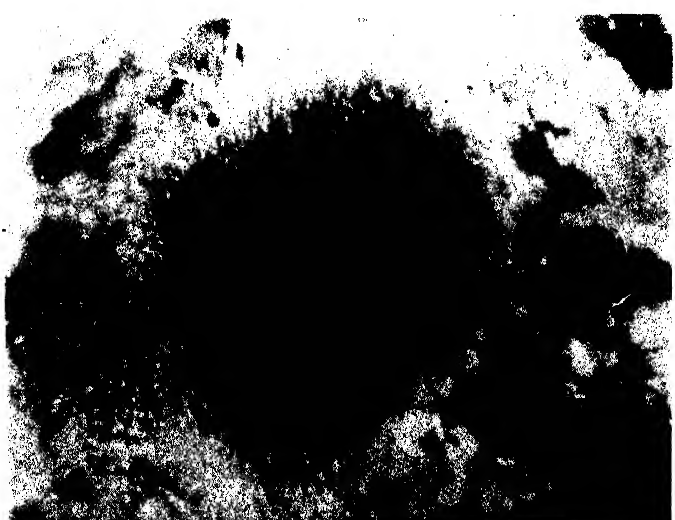


PLATE 8.—A small sclerotium of *R. solani* developing between particles in a tube of soil. × 75.

An attempt was also made to measure the growth of the inoculated fungus without fixing and staining the slides. Thus a core of soil bounded by the four slides (Plate 3) was placed under a direct light binocular dissecting microscope and the growth of the unstained hyphæ followed through the soil from the line of inoculation. But although one could discern the *Rhizoctonia* hyphæ quite easily in the vicinity of the original inoculum, this was not possible near the extremity of growth, especially where the smaller younger hyphæ of *R. solani* were mixed with the hyphæ of other soil fungi. Here the accumulation of mycelium was too confused to permit one to distinguish *Rhizoctonia* under the low resolving power of the dissecting microscope. The same difficulty occurred when the fungus was inoculated into tubes of soil subjected to various treatments. Plates 7 and 8 illustrate how *R. solani* can readily be recognized *in situ* among soil particles in tubes of soil examined under a dissecting microscope. Here again the terminal point of growth

PLATE 9.—A sclerotium among mycelial growth of *R. solani* on a Rossi-Cholodny glass slide taken from the soil.

through such tubes cannot readily be determined, but this technique of study has been used by several other workers, including King, Loomis, and Hope (1931), as a guide to fungus-growth rate in soils of varying characteristics. An attempt to project the picture on slides to a screen was not successful, the reflected detail not being great enough to permit one to recognize the extremities of growth of the inoculated fungus in an accumulation of other organisms. Throughout this work, therefore, the terminal point of *Rhizoctonia solani* spread through the soil was secured by use of a combination of a No. 3 or No. 6 Leitz objective and a 10x ocular used in a reflected light microscope.

Results obtained.—Supplementing the author's published (1942, 1943) discussions on the relation of soil conditions to growth of *R. solani*, the figures (1, 2, 3, and 4) illustrate further the value of the described technique in affording measures of fungus response under a range of soil conditions.

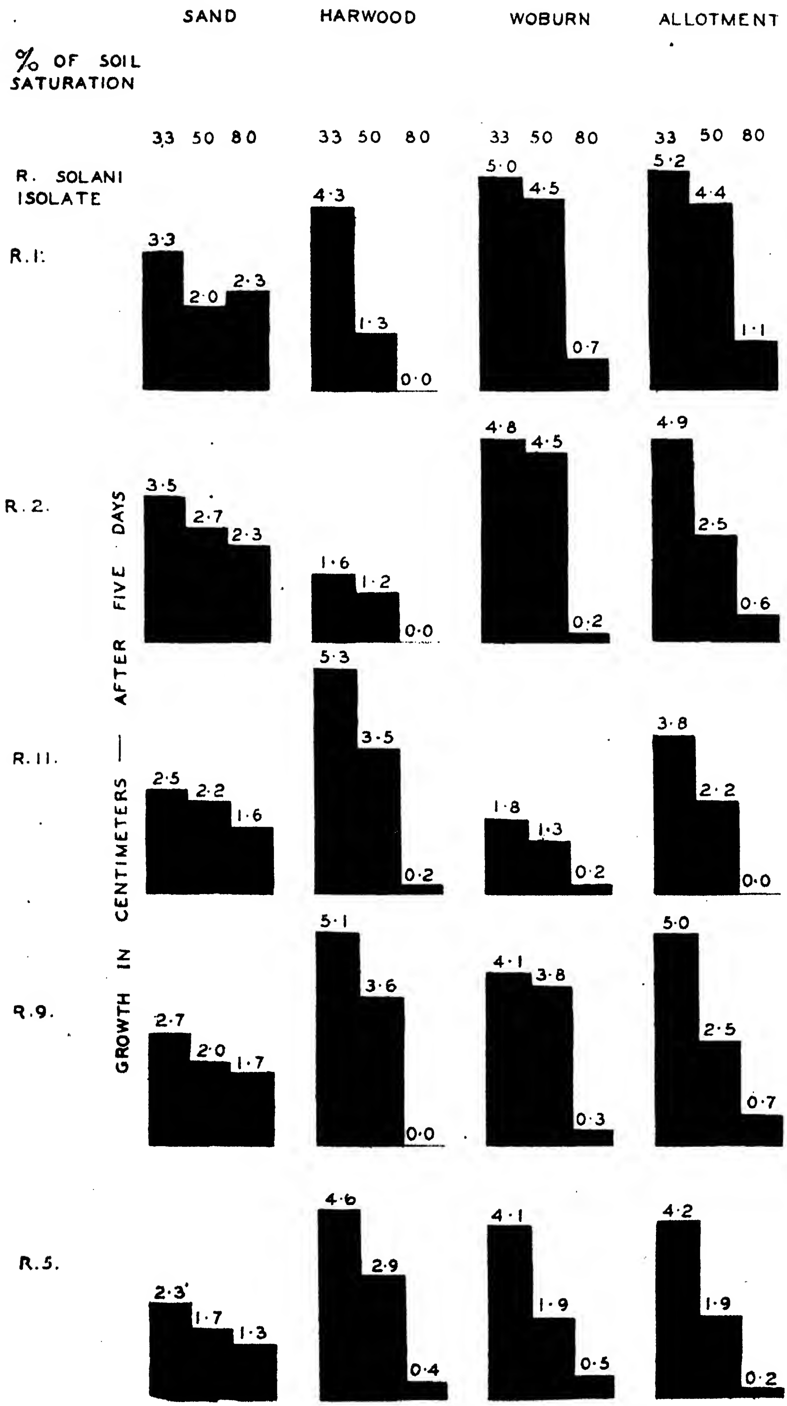


FIG. 1.—The influence of soil moisture on the growth five *Rhizoctonia solani* isolates.

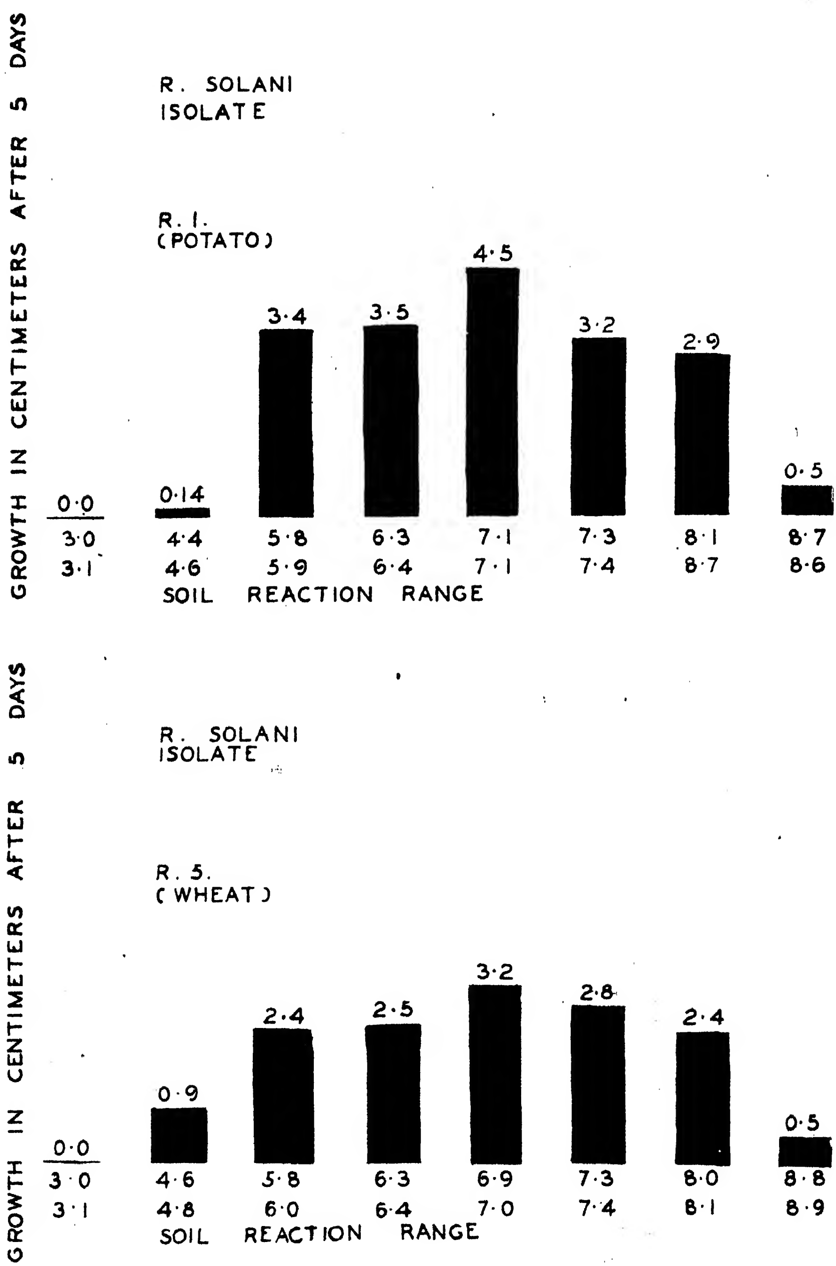


FIG. 2.—The influence of a range of soil reactions on the growth of two *Rhizoctonia solani* isolates.

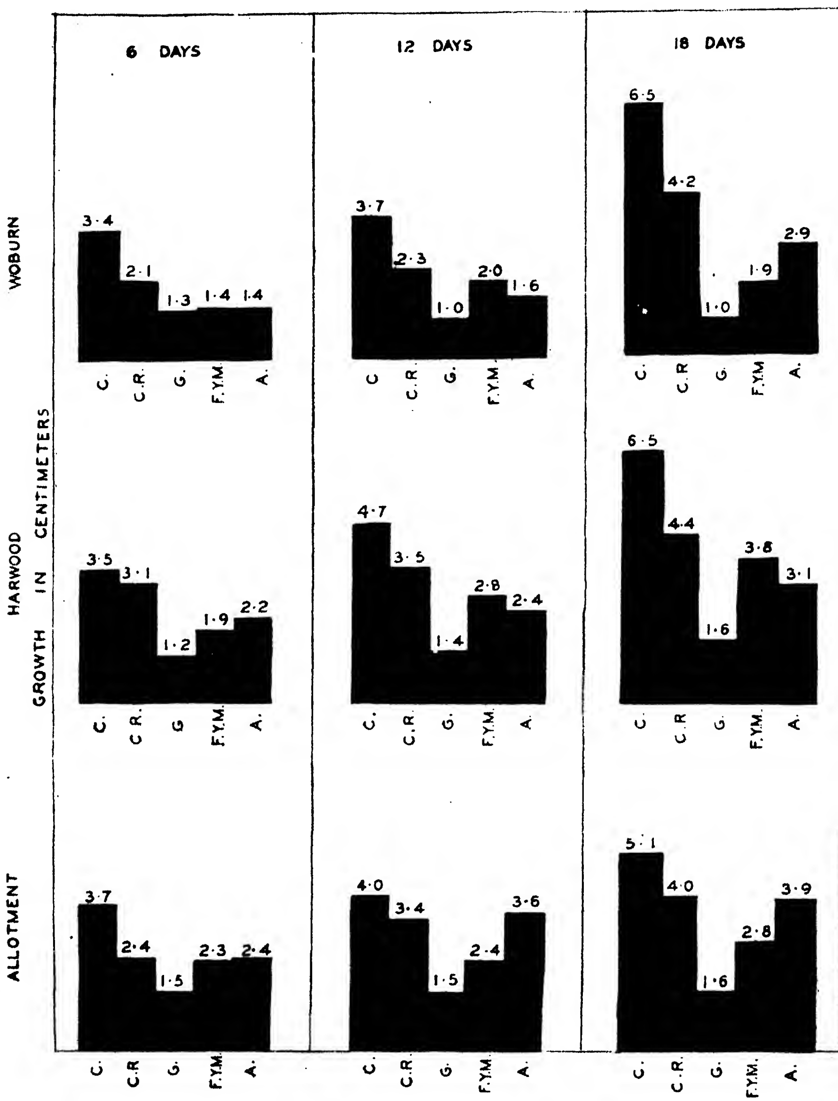


FIG. 3.—The influence of four forms of organic matter on the growth of the R.I. isolate of *Rhizoctonia solani* in three English soils. *Key to symbols:* C. = Control (no organic matter); C.R. = city refuse; G. = grass; F.Y.M. = farmyard manure; A = Adco.

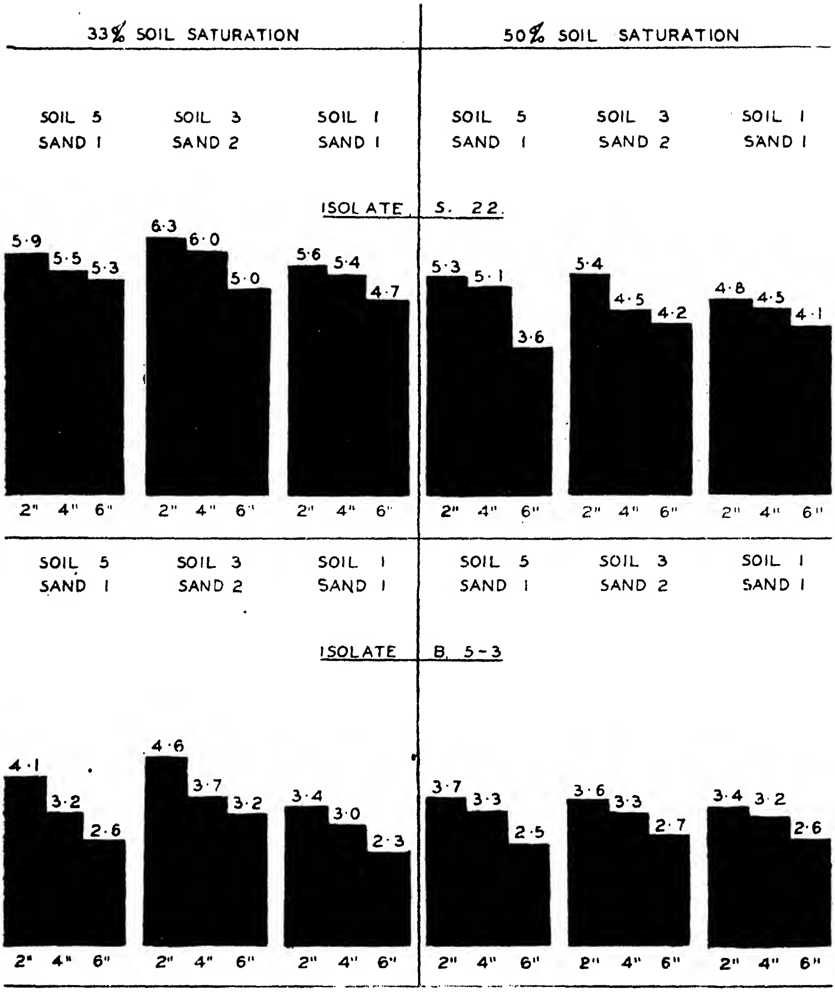


FIG. 4.—The growth of two *Rhizoctonia solani* isolates at three levels of depth in the soil (in centimetres twelve days after inoculation).

REFERENCES

BLAIR, I. D. (1942): Studies on the Growth in Soil and the Parasitic Action of certain *Rhizoctonia solani* Isolates from Wheat. *Can. J. Research*, *20*, 174–185.

——— (1943) Behaviour of the Fungus *Rhizoctonia solani* Kühn in the Soil. *Annals App. Biol.*, *30*, 2, 118–127.

CHOLODNY, N. (1930): Ueber eine neue Methode zur Bodensuchung der Bodenmikroflora. *Arch. Mikrobiol.*, *1*, 620.

CONN, H. J. (1917): The Direct Microscopic Examination of Bacteria in the Soil. *Abst. Bact.*, *1*, 40.

——— (1932): A Microscopic Study of certain Changes in the Microflora of the Soil. *New York State Agr. Expt. Stn. Tech. Bull.*, *204*.

DUGGAR, B. M., and STEWART, F. C. (1901): The Sterile Fungus *Rhizoctonia*. *Cornell Univ. Agr. Expt. Stn. Bull.*, *186*, 52–54.

EATON, E. D., and KING, C. J. (1934): A Study of the Cotton Root-rot Fungus in the Soil. *J. Agr. Research*, *49*, *12*, 1093–1113.

FLOR, H. H. (1940): Soil Sickness of Flax in North Dakota. *Phytopath.*, *30*, *9*, 749–759.
GARRETT, S. D. (1936): Soil Conditions and the Take-all Disease of Wheat. *Ann. Appl. Biol.*, *23*, *4*, 667–699.
——— (1938): Soil Conditions and the Take-all Disease of Wheat: Decomposition of the Resting Mycelium of *Ophiobolus graminis* in Infected Wheat Stubble buried in the Soil. *Ann. Appl. Biol.*, *25*, *4*, 742–766.
JENSEN, H. L. (1934–36): Contributions to the Microbiology of Australian Soils. 2–4. *Proc. Linn. Soc., N.S. Wales*, *59*, 200; *60*, 145; *61*, 27.
KEEN, B. A., and RACKOWSKI (1921): The Relation between the Clay Content and certain Physical Properties of a Soil. *J. Agr. Sci.*, *11*, 441.
KING, J. C.; LOOMIS, H. F.; and HOPE, C. (1931): Studies on Sclerotia and Mycelial Strands of the Cotton Root-rot Fungus. *J. Agr. Research*, *42*, 827–840.
KOFFMAN, M. (1928): Ein Methode zur direkten Untersuchung der Mikrofauna und der Mikroflora des Bodens. *Centb. f. Bakt.* 2 *Abst.*, *75*, 28–45.
KUBIENA, W. L. (1938): "Micropedology." Collegiate Press Inc., Ames, Iowa, p. 232.
ROSSI, G. M. (1928): L'esame Microscopio e Bacteriologio Diretto del Terreno Agrario. *Nuov. Ann. dell Agr.*, *7*, 457–470.
ROSSI, G. M., and GESUE, G. (1930): Di un Nuovo Indirizzio Nella Studio Biologico del Suolo. *Ann. Tech. Agr.*, *3*, 196–248.
SANFORD, G. B. (1939): Research on certain Soil-borne Diseases as affected by other Micro-organisms. *Sci. Agr.*, *19*, 609–615.
TERVET, I. W. (1937): An Experimental Study of some Fungi Injurious to Flax. *Phytopath.*, *27*, 531–546.
TIMONIN, M. I. (1940): Interaction of Higher Plants and Micro-organisms—II: A Study of the Microbial Population of the Rhizosphere in relation to Resistance of Plants to Soil-borne Diseases. *Can. J. Research*, *18 C*, 9, 444–456.
WAKSMAN, S. A. (1927): "Principles of Soil Microbiology." Williams and Wilkins, Baltimore, 641–642.
——— (1932): "Principles of Soil Microbiology." Williams and Wilkins, Baltimore, 9–12.
WINOGRADSKY, S. (1924A): Sur l'étude Microscopique du Sol. *Acad. Sci. C.R.*, 179, 367.
——— (1924B): La Methode Directe dans l'étude Microbiologique du Sol. *Chim. et Indust.*, 2, No. 2, 1924.
——— (1925): Etudes sur la Microbiologie du Sol. *Ann. Inst. Past.*, *39*, 1–56, 299–354.

EXPERIMENTS IN POULTRY-BREEDING

By ERNEST P. NIELSEN, New Zealand Dairy Board

[*Received for publication, 23rd June, 1944*]

Summary

From a White Leghorn, Black Leghorn, and Bantam base involving but three individual birds, four new breeds have been developed that are breeding true for their distinguishing characters, while a further four breeds are in the process of being fixed.

The development of autosexing breeds from the same source has occurred. Autosexing has been relatively easy to fix in stock carrying the barred factor.

It has been clearly demonstrated that intense inbreeding can be carried on over at least six generations without in any way impairing the vitality of the progeny concerned, always provided that the nucleus stock possess such vitality.

The many characters which combine to distinguish one breed from another (in this case those carried by the White Leghorn) can be fixed in subsequent generations by intense inbreeding, even when crossed with other breeds.

The influence of characters from the second breed may also manifest themselves throughout the generations.

That an understanding of Mendelian laws of inheritance makes it possible by selective breeding to fix particular characters and to eliminate others from a line of stock.

"*Thirty years from to-day breeders will hardly believe that, even as late as 1930 or thereabouts, people were so foolish as to think that selection for show points in cattle was helping to build up the correct*

sort of constitution, or that licensing of stud stallions was still done without any relation to progeny testing, or that there were countries in Western Europe where a system of selecting poultry based upon the production of individual hens was forced upon the breeders by the Government."—HAGEDOORN(1).

HERE in New Zealand at the dawn of 1944 Hagedoorn's words regarding "1930 or thereabouts" still apply in the general sense to the breeding of our domestic animals and birds. As emphasized by a recent report on the improvement of dairy cattle in New Zealand, straight selection on a phenotype basis not only continues to dominate breeding methods, but also has signally failed to improve the efficiency of our dairy herds over the past thirty years. Sheep, pigs, and poultry are likewise bred with practically no regard to the findings of modern genetics and on a basis which long experience, without the need for scientific analysis, has shown to produce little change in the quality and characteristics of successive generations. Despite this, there is an increasing interest in applied genetics, and it is stimulating to find that the discoveries of Hagedoorn(1), Punnett(2), and others in the feathered world can be practised at will with similar results by those who have the inclination. In this paper is presented the results of a series of breeding experiments which it is hoped may stimulate breeders not only of poultry, but also of other stock, to investigate the possibilities of applying the principles of genetics to practical animal-breeding.

In 1935 it was decided to attempt the establishment of a bantam breed which would be the miniature of a White Leghorn. The nucleus was found in a select linebred White Leghorn male, while his mate was a Bantam of a breed commonly found on farms in New Zealand, but of which there is no record of identity or heredity. This bird showed the following characters :—

Black hackle laced with silver.
Body Feathers : Flecked grey and light brown, laced with white.
Breast : Salmon.
Low egg-yield, with strong tendencies to broodiness.

The influence of the White Leghorn was very evident in the F_1 generation, and has remained so throughout subsequent generations (Plate 1). As early as 1902 it was known that the white of the Leghorn behaves as a dominant to colour(2). Of the F_1 progeny, one male and ten females were all white except for a few black feathers in some of the females. As was to be expected, body size was considerably raised over that of the bantam female, the F_1 male weighing 4 lb. and the F_1 females 3 lb.—the latter being remarkably uniform. The egg-yield was raised to a reasonable level, and tendency to broodiness was almost eliminated—one hen only showing this character towards the end of the second laying season.

The F_1 male was mated with the F_1 females, and the resultant F_2 generation gave the following progeny :—

Three white males showing brassiness.
One white male showing slight barring.
One white female.
One white female with dark legs and skin.
One cuckoo female with soft indistinct barring ; odd white feathers in the wing primaries. Yellow legs.
One black female showing a few white-tipped feathers round the hocks.

It is interesting to note that, although working with very small numbers through lack of space, the cuckoo or barred bird made its appearance (F_2, Plate 1). According to Punnett(2), workers have long concluded "that the White Leghorn is constitutionally a cuckoo, which is at the same time homozygous for the pigment-inhibiting factor and thus wherever the White Leghorn has been crossed with a coloured breed, cuckoo or barred

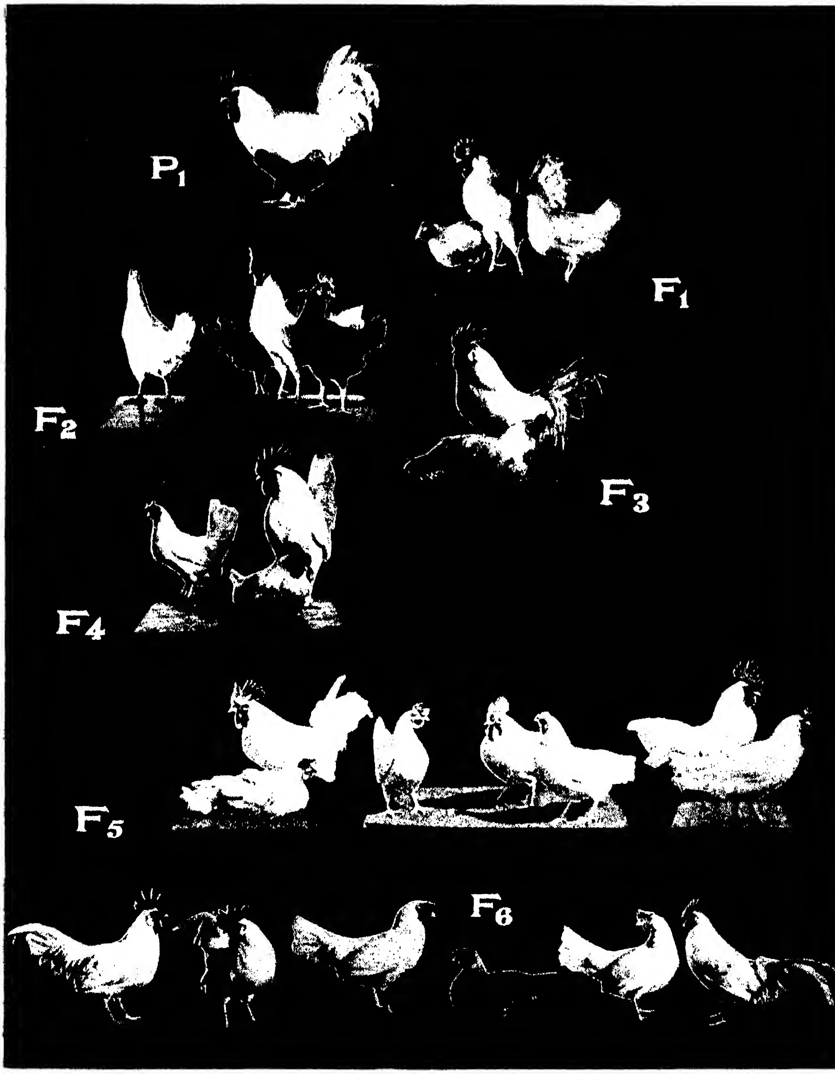


PLATE 1.

birds have manifested themselves in the F_2 generation." Of this F_2 generation (Plate 1), three males were destroyed after having selected for breeding the one which most closely conformed to White Leghorn characters. This bird weighed 3 lb., while the weights of the females were—

	lb.	
Cuckoo	$3\frac{1}{4}$	
White (two)	$2\frac{3}{4}$	(average)
Black	2	

This selected F_2 cock was tested for homozygosity for white by a mating with his F_2 black sister (Plate 3). The resulting progeny all being white except for a few black feathers in the females permitted the conclusion that he was homozygous for the inhibiting factor upon which dominant white depends. A possible explanation for the odd black feather in the female progeny has been provided by Punnett(2) as due to the absence of the sex-linked barring factor or other additional factors upon which complete suppression of pigmentation depends.

Mated thereafter to his white F_2 sister, the resultant F_3 generation (Plate 1) produced three white males and three white females, the latter also showing the odd black feather. One female showed slight "pile"—*i.e.*, rust or light brown on the breast. The males particularly were outstanding in Leghorn character, but the bird selected to breed from developed into a somewhat heavier specimen than desired, weighing just over 4 lb. He was mated with his F_3 sisters.

The F_4 generation (Plate 1) gave one white male of $2\frac{1}{4}$ lb. at maturity, thus bringing him into the bantam class whilst still conforming to the Leghorn ideal in other respects. The second male (there were two only in this group) was white and very lightly barred.

The three females, white with occasional black feathers, conformed closely to Leghorn type and laid well. No records of laying capacity had hitherto been kept, and these only from 20th July till the end of January. One of the three was sick from 12th August till 4th October, failing to produce during this period. The average was 119 eggs. This compares favourably with the production of White Leghorns of the same age for this period of the year.

The F_5 generation (Plate 1) were the result of mating the F_4 white male with his three white sisters. In this group there were three white males all well within the bantam range. Their mature weights were $2\frac{1}{4}$ lb., $2\frac{1}{4}$ lb., and 2 lb. respectively. Four white females showed occasional black feathers and body weights of $2\frac{1}{4}$ lb. each. Three other females showing slight "pile" on the breast were somewhat heavier than their sisters. For these reasons they were discarded from the breeding-pens.

The two heavier males were mated in turn with three of the four white females. From the first male only four chicks were hatched from eight eggs, to provide the present generation (F_6, Plate 1). One female is a very light grey, while another white female has a black feather on the neck; and the two males are all white. From the second male five chicks were hatched, and of these one male is white and very lightly barred, while the remaining four are white.

The third male and remaining female of this F_5 generation have thus far produced eight chicks which were all white. They were hatched by a somewhat flighty hen and perished. This third F_5 male, having been proven homozygous for white, will now be used on his four sisters.

These birds of the F_6 generation (Plate 1) show no lack of vitality and no difficulty has thus far been experienced in rearing, in spite of brother and sister mating throughout the six generations. It is worthy of note, also, that through lack of space the birds have all been cage bred with no outside runs and only first-year birds have been bred from.

Although the primary intent was to produce a white bantam of Leghorn type which even when fixed as a pure breed would only be of interest to a fancier, points of practical value have come to the surface in its evolution even thus far.

DEVELOPMENT OF AUTOSEXING BREEDS

Through the introduction of a third outside bird, a Black Leghorn male, it has been possible to isolate and form the nucleus of at least eight distinct varieties, three of which are worthy of mention in some detail. One of them has showed itself an autosexing breed, while another promises to behave in a like manner.

Autosexing, first demonstrated by Punnet and Pease, of the University of Cambridge, is of considerable practical significance.

The question arose as to whether or not the cuckoo condition could be easily fixed. The cuckoo female from the F_2 generation (F_2, Plate 2, top) was mated back to her white sire of the F_1 generation (see page 274, and F_1, Plate 2, top). This mating resulted in two males with—

White silver hackle, showing some grey feathers.
Back and breast mainly white, showing grey and a few brown feathers.
Tail: Grey with some green feathers.
Thighs: Light barred.
Showing barring in neck and saddle hackle.
Leg colour: Yellow. Leghorn type.

A third male was white and lightly barred, while a fourth was white.

One female—
White with a few black feathers.

Two females—
Black with very light peppering on the body.
Neck showing silver.

(See group A, Plate 2, for above birds.)

The P_1 generation of this barred breed was one (P_1♂, Plate 2) of the two males of which a description has been provided above mated back to the original F_2 cuckoo female (P_1♀, Plate 2). The result of this mating was four males similar to their sire but more definitely barred (F_1, Plate 2, bottom):—

Very slight odd brown shading on the wing bag.
The main tail sickles were half white.
The legs were yellow and mottled with black.

A fifth male was white and very lightly barred with yellow legs, and may be described as having a typical American Leghorn head with a perfect cream lobe.

There was only one female (F_1, Plate 2, bottom), which had a soft grey barring with no white or black feathers.

Two of the four darker males were destroyed without mating, the other two being used alternately with their sister. Eight chicks were hatched from the first, resulting in two barred males and six females black with silver peppering (F_2, Plate 2, bottom). The second male gave similar results. The white male has yet to be proven, but from previous experience there is little doubt but that he will prove homozygous for the barring factor. The purpose in proving the darker males was prompted by the desire to fix a breed where the barring was equally decided in both sexes.

The result thus far with this and a second barred line, to which reference will be made later, coincide with that which Punnett(2) has placed on record regarding the Plymouth Rock breed:—

The barring factor is to be regarded as a partial inhibition of pigment production. Normal barred birds, such as Plymouth Rocks, are genetically full blacks to which the

barring factor has been added. The effect of this factor is to inhibit the production of the black pigment, almost eliminating it in the light areas of the feather, and diminishing it in the darker ones. At the same time it prevents the pigment from appearing on the shanks. Breeders of Plymouth Rocks know that they frequently throw blacks, and that in such cases the blacks are always hens with dark shanks. The frequency with which blacks appear is probably due to the fact that the fancy has decreed that the

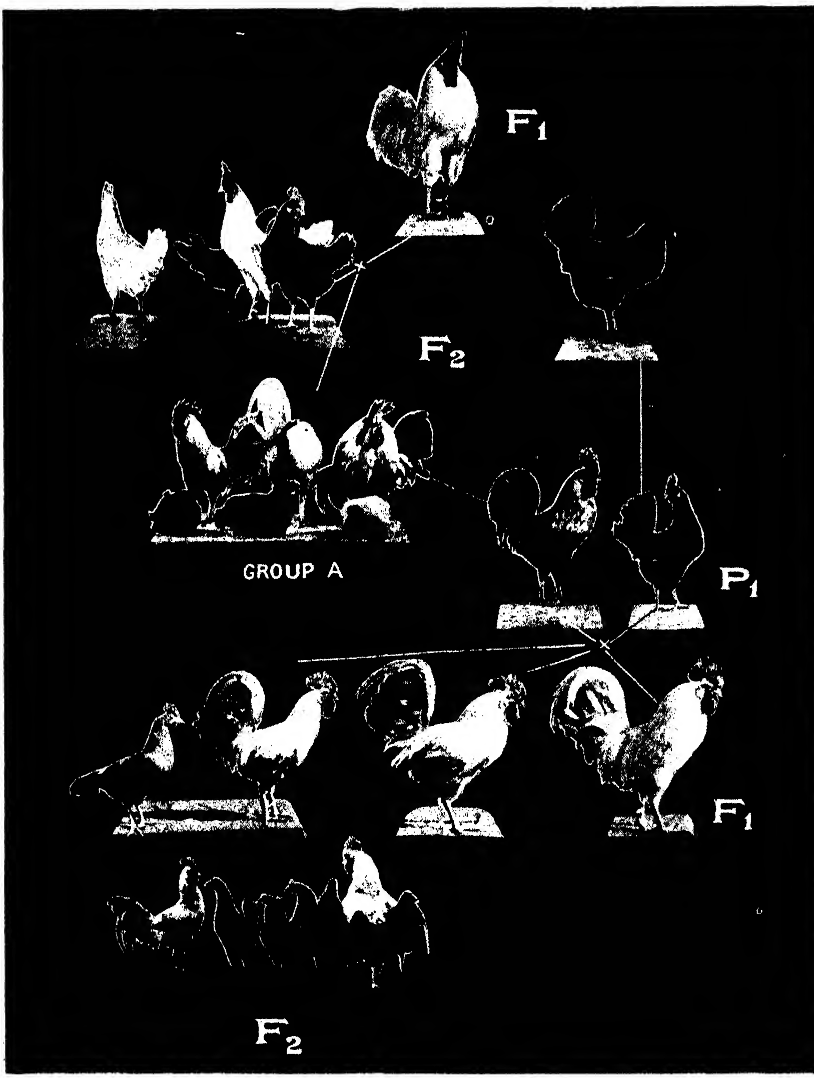


PLATE 2.

cock shall be as far as possible the counterpart of the hen in the depth of pigmentation of the bars. This means that the show cock is usually heterozygous for the barring factor; for the homozygous cock that has received the factor from both parents is too light for successful exhibition. The hen, of course, is always heterozygous. Consequently if the exhibition cock is used to breed from, we may look for black pullets among the offspring.

This cuckoo or barred line have been styled "Personians," and their pedigree is as under :—

- Cuckoo Personian P_1♂
  - F_1 White♂
    - White Leghorn♂
    - Bantam♀
  - Cuckoo F_2
    - F_1 White♂
      - White Leghorn♂
      - Bantam♀
    - F_1 White♀
      - White Leghorn♂
      - Bantam♀
- Cuckoo F_2 Personian P_1♀
  - F_1 White♂
    - White Leghorn♂
    - Bantam♀
  - F_1 White♀
    - White Leghorn♂
    - Bantam♀

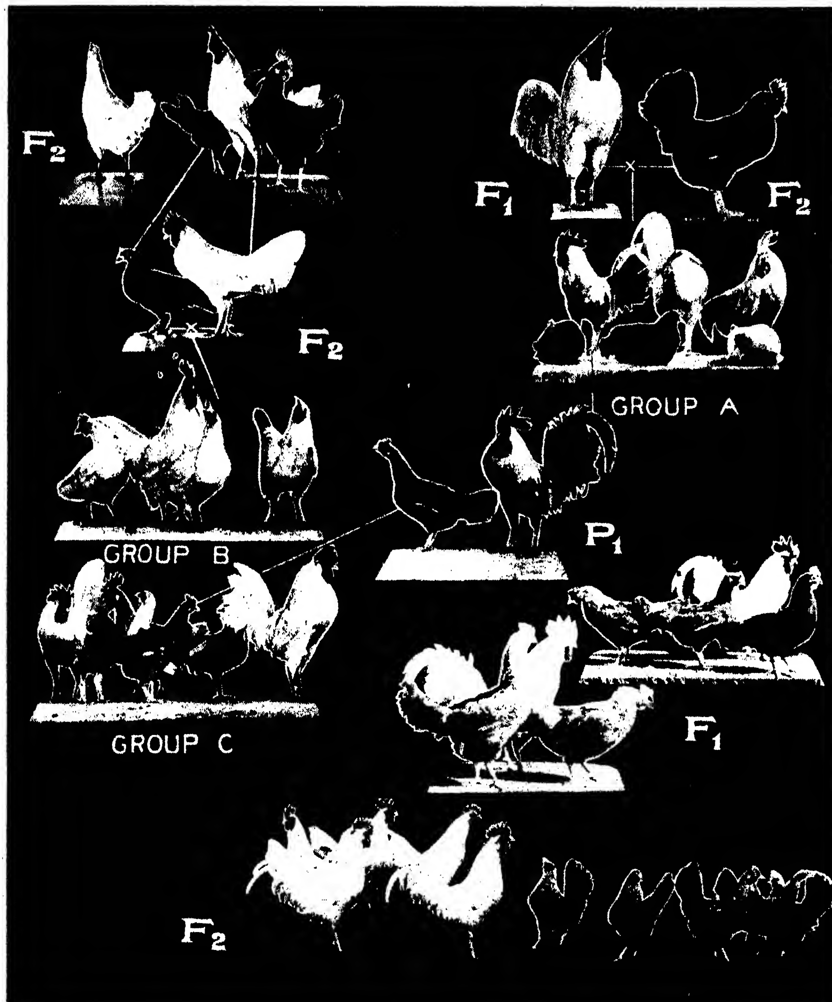


PLATE 3.

For the reasons already cited and because of the very marked differences between the white lightly barred male and the dark female, there is every possibility of fixing the Personian as an autosexed breed almost identical with another line—the "Drybar," which is already proven as autosexed in the F_2 generation.

In the proving of the F_2 white male in the white bantam line it will be remembered that he was mated with his F_2 black sister (F_2, Plate 3, top left), which resulted in white males and females, the latter showing odd black feathers (Group B, Plate 3). The birds were very strong in Leghorn character, and in the hope of establishing a black line they were brother and sister mated. This resulted in two white males showing brassiness and one black male heavily laced with white, or silver on the neck and saddle hackle. There were three white females with odd black feathers and one female with a general soft grey barring with a few solid black feathers, legs, yellow (Group C, Plate 3). The black male was mated with his sisters, but the seven chicks hatched were white with occasional black feathers. There being other more interesting developments, this project was discontinued.

This line, however, provided an important bird in so far as the autosexing Drybar is concerned. The barred female (P_1♀, Plate 3) was mated to the second barred male (P_1♂, Plate 3) produced from the original cuckoo F_2 female when mated to her F_1 white sire (see F_1 and F_2, top right, Plate 3). Only four chicks were hatched (F_1, Plate 3, bottom):—

One white male showing brassiness, very slight traces of barring on thigh and underparts of tail. Legs, yellow. Lobes, red and cream. Leghorn type.

Two females: General soft grey barring with a few solid black feathers. Legs, yellow. Leghorn characteristics.

The fourth was a jet-black female.

The male was mated with his barred sisters, and of some forty chicks hatched all were barred.

Barred chicks are distinguishable at hatching by a yellowish-grey patch at the back of the head in the occipital region(2).

Twelve chicks are being reared—six of either sex, the males being the counterpart of their sire and the females of their dams (F_2, Plate 3, bottom). The difference in colour is very distinct at hatching, the down of the male being decidedly lighter in colour. This was also the case with the F_1 generation.

The pedigree of the Drybar is given below:—

- Cuckoo♂ P_1 Drybar
  - White F_1♂
    - White Leghorn♂
    - Bantam♀
  - Cuckoo F_2♀
    - White F_1♂
      - White Leghorn♂
      - Bantam♀
    - White F_1♀
      - White Leghorn♂
      - Bantam♀
- Cuckoo♀ P_1 Drybar
  - White♂
    - White F_2♂
      - White F_1♂
        - White Leghorn♂
        - Bantam♀
      - White F_1♀
        - White Leghorn♂
        - Bantam♀
    - Black F_2♀
      - White F_1♂
        - White Leghorn♂
        - Bantam♀
      - White F_1♀
        - White Leghorn♂
        - Bantam♀
  - White♀
    - White F_2♂
      - White F_1♂
        - White Leghorn♂
        - Bantam♀
      - White F_1♀
        - White Leghorn♂
        - Bantam♀
    - Black F_2♀
      - White F_1♂
        - White Leghorn♂
        - Bantam♀
      - White F_1♀
        - White Leghorn♂
        - Bantam♀

DEVELOPMENT OF "MEEKAMS"

Another important step was the fixing of a black line. No F_2 black male having appeared, the F_2 black female (F_2♀, Plate 4) was mated with a Black Leghorn male typical of his breed (Plate 4, top left). This Black

Leghorn introduced the third bird to the parent stock from which all the lines have evolved—*i.e.*, the Black Leghorn, the original White Leghorn male, and bantam female.

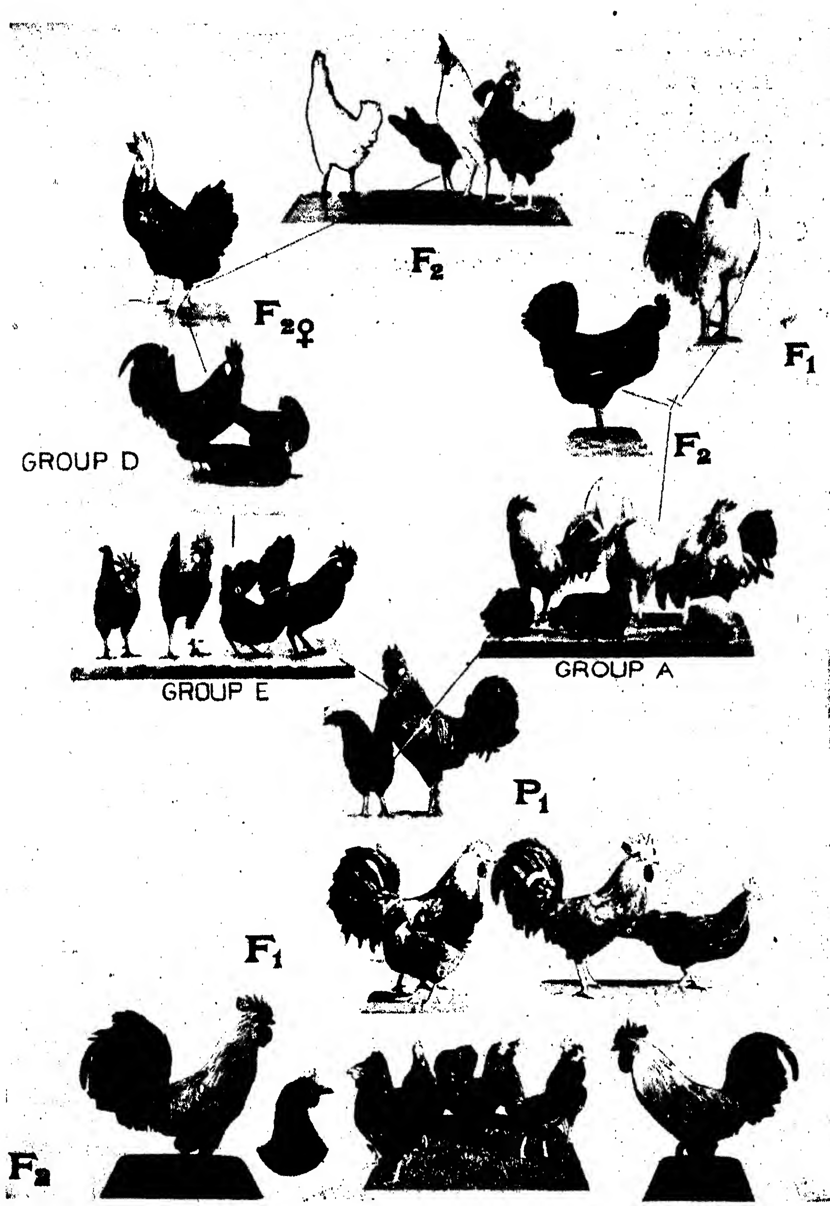


PLATE 4.

The result of this Black Leghorn male × black F_2 female mating was five black males with gold feathers appearing in the neck and saddle hackle (Group D, Plate 4). Four were destroyed prior to the full development of colour. The male kept to breed from was heavily laced gold and silver.

All these males had yellow legs. There were two jet-black females in this group with slate legs. The eggs were counted from these two birds from 20th August to 30th December, during which time they averaged 92 eggs. Mated to their brother, only four chicks were reared, three males and one female (Group E, Plate 4):—

One black male—

Heavily laced with light gold.
Breast: Pure black.
Hock: Smudged light.
Tail: Black and light at base.
Legs: Pure yellow.

One black male—

Heavily laced with white or silver on neck and saddle hackle.
Tail: Black and showing beetle green.
Breast: Black with odd white fleck.
Legs: Black.

The third male was jet black with odd gold feathers.

The female was also black.

These black lines have been bred on and have given rise to two other distinct lines in addition to a third, which appears fixed, and for that reason will be dealt with here.

In the group of birds (Group A, Plate 4) produced from the F_2 cuckoo (previously referred to) mated to her F_1 white sire there were two black females showing silver on the neck with very light peppering on the body. One of these birds was mated to the heavily laced silver over black male from the black line (P_1♂ and P_1♀, Plate 4). This resulted in a pair of birds identical with their parents. In a second pair from the same mating the male has a neck hackle with the top black and heavily laced silver. The bottom of the hackle is black laced with gold (F_1, Plate 4, bottom). Gold is also showing in the saddle hackle. The wing bay is black and splashed with white and gold. The female is jet black with a peppering on the top part of the neck.

The heavily laced male was mated with his sister and there are two males and six females identical with their parents (F_2, Plate 4, bottom). These have been styled Meekhams.

The pedigree of the P_1 generation is as follows:—

- Meekams
  - Black Silver♂ P_1
    - Black♂
      - Black Leghorn♂
      - Black F_2♀
        - White F_1♂
          - White Leghorn♂
          - Bantam♀
        - White F_1♀
          - White Leghorn♂
          - Bantam♀
    - Black♀
      - Black Leghorn♂
      - Black F_2♀
        - White F_1♂
          - White Leghorn♂
          - Bantam♀
        - White F_1♀
          - White Leghorn♂
          - Bantam♀
  - Black Silver♀ P_1
    - White F_1♂
      - White Leghorn♂
      - Bantam♀
    - Cuckoo F_2♀
      - White F_1♂
        - White Leghorn♂
        - Bantam♀
      - White F_1♀
        - White Leghorn♂
        - Bantam♀

DISCUSSION

These experiments were not designed to study the genetics of poultry and should not be regarded in any way as aiming at such an objective. The number of breeds with which it has been possible to deal rules out any attempt at genetic analysis. Rather should they be regarded as a "back-yard" demonstration of the possibility of applying existing knowledge of genetics to the development of domestic stock.

The experience with inbreeding without the appearance of any recognizable deleterious effects, but rather with an increase in the reliability of breeding animals showing high vitality, is in itself of considerable interest. The relative ease with which so many distinct lines or "new breeds" have been either entirely or partially developed has its lesson for the stud breeder. He is limited in his operations by popular concepts of "purebred" which prevent him from introducing new characters through crossing likely to lead to improvement over existing types.

ACKNOWLEDGMENTS

The thanks of the author are due to Mr. J. Kissling, Poultry-manager, Massey Agricultural College, for detailed description of the plumage of the birds, and to the New Zealand Dairy Board, which contributed towards the maintenance of the flock.

Acknowledgment is also made to Dr. C. P. McMeekan, Animal Research Station, Ruakura, for advice in the preparation of this paper. To Mr. F. E. T. Suckling, Grasslands Division, for photographing birds of the last generation, and to P. Nielsen, jun., for preparation of photographs.

REFERENCES

(1) HAGEDOORN, A. L. (1939): "Animal Breeding." Crosby, Lockwood, and Son, London.
(2) PUNNETT, R. C. (1923): "Heredity in Poultry." Macmillan and Co., London.

STUDY OF A YELLOW-GREY LOAM IN THE MANAWATU

By C. V. FIFE, Massey Agricultural College, Palmerston North

[*Received for publication, 18th September, 1944*]

Summary

The morphology and field characteristics of the soil are described.

The analytical data reveal the satisfactory base content of the surface soil under rain forest, but point to a marked reduction in the base exchange capacity and an increase in unsaturation in soils from which the forest has been cleared for a considerable number of years.

Iron has moved downwards in the profile, and it is concluded that the greater part of this iron has become segregated in the concretionary material which is mainly concentrated in the upper portion of the B horizon.

THE work reported in this paper was initially undertaken in 1938 with the object of supplementing the meagre information then available concerning the soil type on which the Massey College sheep-farm is situated. Mapping of the genetic soil types in the Manawatu had not at that time been commenced by the Soil Survey Division, but a general survey of the district was

initiated in May, 1939, as part of the general survey of the North Island (now completed). After an interruption of several years the work reported here has recently been brought to its present stage. As the soil type involved falls within the new group of yellow-grey loams,* the results may be of more general interest than would otherwise have been the case. The data presented consist principally of chemical analyses carried out on a limited number of samples collected at Massey College and elsewhere in the district on the same soil type. Considerably more work would be necessary to establish what constitutes the typical profile from a chemical point of view, but the results obtained to date throw some light on the nature of the soil processes involved.

The soil type under consideration has developed under a heavier forest cover than is normal for the yellow-grey loams, and the profiles described have been influenced to the present day, or until recently, by a rain forest association. They have developed on the broad, flat, poorly drained terrace which lies between the foothills of the Tararua Range and the Manawatu River. This terrace forms part of the maritime plain resulting from the coalescence of the fans built up by the Pohangina, Manawatu, Oroua, Rangitikei, Turakina, and Wangaehu rivers. The whole area is represented on Morgan's geological sketch map of New Zealand(2) as composed of Recent and Pleistocene alluvial deposits overlying Pliocene mudstone. A comparatively late uplift has allowed the rivers to excavate the old fans, resulting in the production of valley-plain terraces. The compact river alluvium on which the soils described have developed is derived in part from the greywacke and Tertiary mudstone of the main divide, but considerable proportions of the parent material may have been transported by the Manawatu River from the eastern side of the ranges.

The average local rainfall based on observations made over the past thirteen years at the Massey College and Plant Research Bureau meteorological station is 38 in., varying between the limits of 32 in. and 51 in. The number of wet days each year lies between 150 and 190. The mean temperature is 55° F., and the mean maximum temperature is 62° F.

The two Massey College profiles described were selected from a site still carrying remnants of the rain forest† which formerly covered the entire area now constituting the college sheep-farm‡. Prior to 1936 thick bush covered this site, although stock had damaged the underscrub and grass had become established under the trees. In February, 1936, the bush was severely damaged by a full gale, and when the profile samples were taken in 1938 only scattered trees of tawa, mahoe, titoki, kawakawa, and *Hedycarya* remained. Grass had become firmly established and the area had been grazed, but, as far as was possible to ascertain, had not been top-dressed with lime or fertilizers.

* The yellow-grey loams are reported(1) as being "confined to the lower rainfall areas (35 in. to 50 in.) of Hawke's Bay, Wairarapa, and Manawatu, the native vegetation being light forest, scrub, and bracken fern. They are formed largely from calcareous mudstone and argillaceous sandstones. The true yellow-grey loams are fertile soils with a high pH and are well saturated with bases". Dixon (private communication) states that the soil type described in the present paper is included among the poorer types of yellow-grey loam on the soil map of the North Island now prepared for publication by the Soil Survey Division.

† Aston(3) has noted the following association in virgin forest in the Esplanade Gardens, Palmerston North, which appears also to be fairly typical of the forest which formerly covered the older terrace soils: "tawa, pukatea, and white-pine, with small forest and underscrub of titoki, kawakawa (*Piper*), lacebark (*Hoheria lanceolata*), *Shefflera*, mahoe, *Coprosma grandifolia*, *C. robusta*, wineberry, *Geniostoma*, *Aristotelia racemosa*, *Hedycarya*, ferns and epiphytes . . . "

‡ In 1880, according to the records available on the early history of the property, this area was still under heavy bush, mainly tawa, kahikatea, and pukatea. Felling and burning of the bush was commenced soon after this date.

Further studies have been made on the same soil type at Aokautere. The site selected here, as far as is known, is the only remaining portion of level terrace in the district still under bush, apart from a very restricted area in Anzac Park, Palmerston North. Stock have had some access to the area.

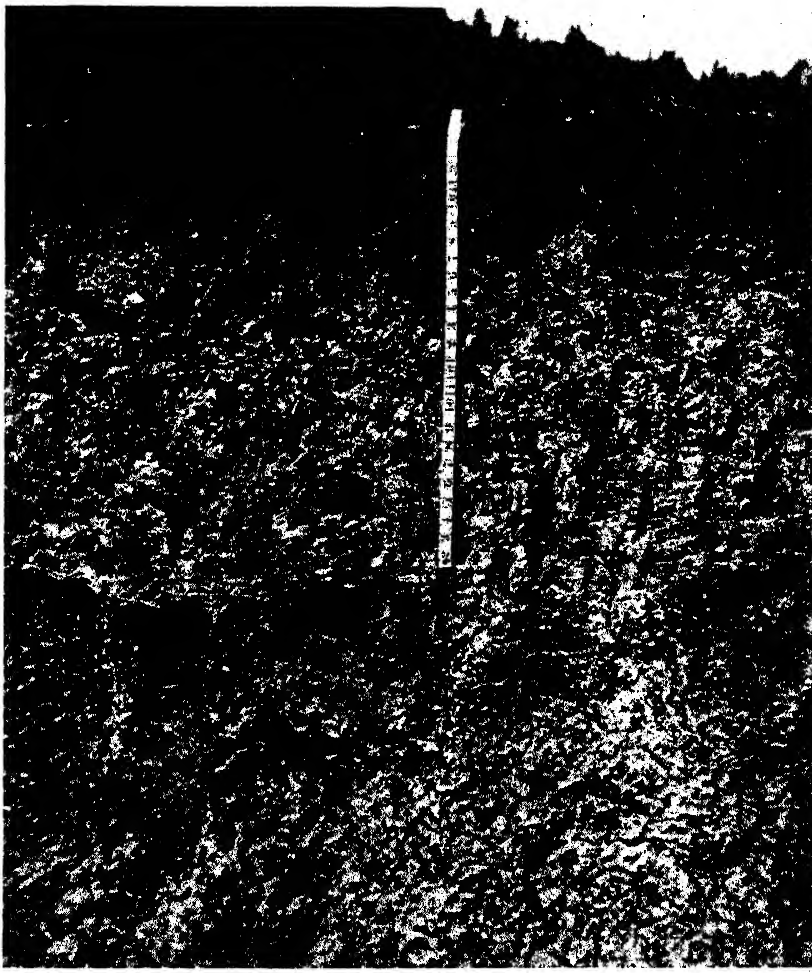


FIG. 1.—Typical soil profile at Massey College. The photograph was taken in a road cutting in the vicinity of Massey College some six months after the cutting was made. The approximate depth of the solum at this point is 27 in.

FIELD CHARACTERISTICS AND MORPHOLOGY

The soils described have poor surface and internal drainage. On undrained pasture land the soil remains excessively wet throughout the winter and early spring for a continuous period of about five months, but in the late spring evaporation and transpiration become sufficiently active to cause a gradual drying out of the profile, a condition which persists until the late autumn. While no comparable observations have been made on the soils under bush, the rusty-mottled subsoil characteristic of a seasonal waterlogged condition is a constant attribute of these soils. The reduced iron colours associated with a more intense anaerobic condition are absent.

The development of the soil profile at Massey College appears to be generally uniform. Apart from slight variations in the depth of the profile, the main morphological variant is the extent of concretionary development in the subsoil. In some profiles concretionary ironstone assumes considerable proportions, and in others appears to be entirely lacking on superficial examination. There is no sharp differentiation into horizons within the profile, and the sampling depths selected for profile 1 and profile 2 were based mainly on differences in compaction, as estimated by relative ease of digging, and on the distribution of concretions. Figure 1 is indicative of the typical profile at Massey College. The grey A 2 horizon reported(4) to develop in some yellow-grey loams is not apparent in the profiles examined, but the grey topsoil gradually lightens in colour with depth due to the decreasing content of organic matter and at the same time develops a yellowish tinge. In the two Massey College profiles this lighter-coloured zone was sampled separately for the purpose of applying chemical tests as an aid to identification. It has been designated the A–B horizon to indicate its transitional nature. Earthworms are plentiful under the rain forest vegetation, and the thorough mixing of the surface layers resulting from their activities is a factor operating against the development of defined horizons in this part of the profile.

Profile 1 was selected as representing a position in which little concretionary iron had formed, whereas profile 2 was selected on the grounds of considerable concretionary development. The two profile pits were situated only some 10 yards apart. In profile 1 the samples were taken covering the full depth of each layer; successive 4 in. depths were sampled in the C horizon for subsequent tests as to uniformity. In profile 2 an attempt was made to sample only the most typical portion of the several layers.

A description of profile 1 follows. The colours described are those of the dried-out profile :—

PROFILE 1 (MASSEY COLLEGE)

Horizon.	Depth.	Description.
	In.	
A	0–4½	Grey friable granular loam.
A–B	4½–11	Light-grey friable loam. Yellow tinge developing with depth and granular structure becoming less pronounced. Some mixing of materials from adjacent layers by earthworms. Occasional small ironstone concretions present.
B	11–17	Creamy-grey loam with strong rusty-brown mottling. Consistence: compact when dry, plastic and sticky when wet. A small development (considerably greater than in the preceding layer, however) of hard, irregular, but roughly rounded iron concretions ranging up to ¼ in. in diameter. Soft incipient concretions also present.
B	17–23	Creamy-grey clay loam with rusty-brown mottling. Consistence: compact when dry, sticky and plastic when moist. Appears to be the main water-holding layer. No obvious concretionary development, but pinhead size ironstone granules become apparent when the moistened material is rubbed in the hands.
B–C	23–30	Creamy-grey loam. Mottling more diffuse and lighter in colour. Becoming less compact than previous layer and easier to dig. No concretions. Transitional.
C	30–34 34–38 38–42 42–46 46–50	Creamy-grey fine sandy loam. Mottling as in preceding layer. Small quantities of vivianite present, but localized in vicinity of old roots.

Profile 2 is essentially similar to profile 1, but there is a considerably greater development of concretionary ironstone in the upper B horizon.

Roots of forest trees penetrate throughout both profiles, but are largely confined to the surface layers. The bulk of the grass roots is concentrated in the A horizon. The colour of the air-dry " fine earth " varies from grey to light grey in the A horizon, depending on the organic matter content, to a lighter grey with a yellowish tinge in the A–B horizon. The B horizon is predominantly yellow. The C horizon is also yellow, but paler than the B horizon.

The studies made on the soil at Aokautere were carried out with the primary purpose of confirming certain observtaions made on the Massey College soil in respect of the base status of the surface horizon. One profile only was examined. A brief profile description follows :

PROFILE 3 (AOKAUTERE)

Horizon.	Depth.	Description.
	In.	
A_0	0–$\frac{1}{2}$	Loose litter of undecomposed leaves overlying dark granular humus about $\frac{1}{4}$ in. thick.
A	$\frac{1}{2}$–5	Light grey loam exhibiting nutty structure.
A–B	6–11	Lighter grey loam. The yellowish tinge noted in this layer in the Massey College profiles is less obvious. A small number of iron concretions ($\frac{1}{8}$ in. in diameter), with occasional larger ones up to $\frac{1}{4}$ in. diameter, present.
B	12–18	Creamy-grey loam with rusty-brown mottling. Concretionary development somewhat more extensive than in previous layer.
B	19–26	Creamy-grey clay loam with rusty mottling. This layer contained a large number of earthworms and was still quite moist, while the upper portions of the profile had dried out very thoroughly consequent on a prolonged spell of dry weather.
B–C	27–32	Creamy-grey loam. Less compact than preceding layer.

DISCUSSION OF THE LABORATORY DATA*

(i) *Mechanical Composition.*—The textural development in profiles 1 and 2 is comparable with that of other Massey College profiles previously described by Hudson and Fife(5). In Table I mechanical analyses for profile 1 are presented. Those for profile 2 correspond very closely. The virtual absence of coarse sand is worthy of note. In some horizons this fraction is mainly ironstone. A similar distribution of sands is to be found in the soils of the Massey College dairy-farm, situated on the present-day river-flats. Aston(6) has stated that coarse sand is not present in amounts greater than 4 per cent. in most of the land bordering the Manawatu River.

Concretionary ironstone is the only material retained by the 2 mm. sieve. The 11 in. to 17 in. layer in profile 1 contained 3 per cent., while the 11 in. to 16 in. layer in profile 2 contained 20 per cent. of ironstone concretions above 2 mm. in diameter.

* Unless otherwise indicated, all percentages are calculated on oven-dry " fine earth."

(ii) *Organic Carbon and Nitrogen.*—Table I shows the progressive decrease in organic carbon and nitrogen throughout profile 1. Profile 1 is characterized by a particularly high organic matter content in the surface soil. The loss on ignition data for profile 2 showed a similar general distribution of organic matter with depth in this profile, but the surface soil contained considerably less humus. The loss on ignition figures for profile 3 coincided closely with those presented for profile 2.

A preliminary survey of the area from which the profile samples at Massey College were taken revealed considerable variations in loss on ignition in the surface soils from point to point. With respect to the organic matter content of the surface soil, profiles 1 and 2 appear to represent extremes. The average value based on loss-on-ignition figures for the soil at Massey College and elsewhere lies closer to that found for profile 2 (10·6 per cent. loss on ignition) than that found for profile 1.

(iii) *Soil Reaction.*—The wide differences in pH observed under rain forest associations near Dunedin, due to the influence of individual forest species on the soil in their immediate vicinity, have been remarked on by Thomson and Simpson(7). The pH of the soils examined under mahoe and kahikatea, both of which are of interest from the point of view of the present study, either decreased with depth or remained uniform, while under *Nothofagus menziesii* associations the surface soils were generally the most acid.

The presence of a surface pH mosaic in the vicinity of the profile sites at Massey College was indicated by the range of values (pH 5·2–6·9) obtained for a series of samples taken at random from this area. Further evidence is afforded by the pH values presented in Table IV for the soil under rain forest at Aokautere. While animal droppings cannot be neglected as a contributing factor, this variation in surface pH must largely be due to the influence of the forest cover. No attempt has, however, been made to determine which pH values are characteristic of individual species.

The change in pH with depth in profiles 1 and 2 is shown in Tables II and III. In profile 1 a marked increase in acidity occurs in passing down the profile, followed by a decrease in the C horizon. In profile 2, after a slight decrease in the A–B horizon, the acidity again reaches its maximum in the B horizon, but the profile as a whole is less acid. In profile 3 a similar trend in pH was found, but the gradient was less pronounced. In the light of the pH values obtained for the random soil borings on the site of the Massey College profiles, profiles 1 and 2 typify a moderately high and a moderately low degree of acidity with respect to their surface horizons.

The general tendency towards an increase in acidity with depth has also been noted under rain forest in Anzac Park, Palmerston North, on the same soil type and on a recent alluvial soil under rain forest in the Esplanade Gardens, Palmerston North. Both areas are uninfluenced by stock and carry a layer of forest litter. On the latter soil in some cases, however, the pH remained fairly uniform with depth. Further evidence of the presence of a surface pH mosaic was also obtained from these soils.

(iv). *Base Status.*—Little published information is available on the ash content of the leaves or the base status of the litter from the main forest species characteristic of the localities under consideration. The leaves of mahoe possessed the highest ash content of the forest trees investigated by Thomson and Simpson(7), and the leaves of kahikatea also possessed a high ash content in comparison with those of some other conifers. No corresponding data are available for tawa and pukatea. Taylor and Dixon(8) state that the litter of dicotylus trees such as puriri, kohekohe, and taraire

TABLE I.—MECHANICAL ANALYSIS, LOSS ON IGNITION, AND DISTRIBUTION OF ORGANIC CARBON AND NITROGEN IN PROFILE 1

(Fractions dried at 105°)

Soil No.	Horizon.	Depth.	Coarse Sand.	Fine Sand.	Silt.	Clay.*	Loss on Ignition.	Total C.	Total N.	C/N Ratio.
		In.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	
T 156 ..	A ..	0–4½	0·4	46·3	19·1	20·5	18·2	9·4	0·67	14·1
T 157 ..	A–B	4½–11	0·5	50·9	21·4	23·5	5·6	2·9	0·22	13·4
T 158 ..	B ..	11–17	0·6	52·5	22·4	25·1	4·1	1·5	0·11	13·3
T 159 ..	B ..	17–23	0·7	50·5	21·3	28·8	3·5	0·6	0·06	9·5
T 160 ..	B–C	23–30	0·1	54·0	20·6	26·8	3·0	0·2	0·04	6·0
T 161 ..	C ..	30–34	0·1	56·6	20·2	23·7	2·8	..	..	..
T 162 ..	C ..	34–38	0·1	58·2	20·9	21·5	2·7	..	..	..
T 163 ..	C ..	38–42	0·1	58·1	21·1	21·5	2·6	..	..	..
T 164 ..	C ..	42–46	0·1	60·1	20·5	21·1	2·6	..	..	..
T 165 ..	C ..	46–50	0·1	60·6	20·3	20·5	2·5	..	..	..

* Including sesquioxides dissolved in pretreatment.

TABLE II.—BASE STATUS AND REACTION IN PROFILE 1

Soil No.	Horizon.	Depth.	Exchangeable Cations.			Total Exchangeable Bases.	Proportion of Total Bases present as—		Exchange Capacity.	Base Saturation.	pH.
			Ca.	Mg.	H.		Ca.	Mg.			
		In.	m.e. per Cent.	m.e. per Cent.	m.e. per Cent.	m.e. per Cent.	Per Cent.	Per Cent.	m.e. per Cent.	Per Cent.	
T 156 ..	A	0–4½	17·3	6·5	14·3	24·8	70	26	39·1	63	5·6
T 157 ..	A–B	4½–11	4·2	2·4	10·1	7·6	55	32	17·7	43	5·1
T 158 ..	B	11–17	1·6	1·7	9·3	3·6	44	47	12·9	28	4·7
T 159 ..	B	17–23	2·0	2·9	8·4	4·9	41	59	13·3	37	4·6
T 160 ..	B–C	23–30	2·7	4·3	7·6	7·0	39	61	14·6	48	4·5
T 161 ..	C	30–34	3·7	5·4	5·8	9·0	41	59	14·8	61	4·9
T 162 ..	C	34–38	3·9	6·0	..	9·8	40	60	..	..	5·0
T 163 ..	C	38–42	4·3	6·7	..	10·9	39	61	..	..	5·1
T 164 ..	C	42–46	4·6	6·8	..	11·3	40	60	..	..	5·2
T 165 ..	C	46–50	..	..	..	..	..	..	..	..	5·2

TABLE III.—BASE STATUS AND REACTION IN PROFILE 2

Soil No.	Horizon.	Depth.	Exchangeable Cations.			Total Exchangeable Bases.	Proportion of Total Bases present as—		Exchange Capacity.	Base Saturation.	pH.
			Ca.	Mg.	H.		Ca.	Mg.			
		In.	m.e. per Cent.	m.e. per Cent.	m.e. per Cent.	m.e. per Cent.	Per Cent.	Per Cent.	m.e. per Cent.	Per Cent.	
T 84 ..	A	0–4½	11·4	2·9	4·8	16·4	70	18	21·2	77	6·4
T 85 ..	A–B	8–11	3·7	2·3	3·2	6·6	56	35	9·8	68	6·5
T 86 ..	B	11–16	2·5	..	3·6	6·3	40	..	9·9	63	5·8
T 87 ..	B	18–21	2·2	..	7·0	8·4	26	..	15·4	56	5·1
T 88 ..	B–C	25–29	2·4	5·1	6·2	9·6	25	53	15·7	61	5·1

contain more lime and potash than kauri. The alkalinity of the litter ash places the trees investigated by these workers in the order puriri, taraire, rimu, kauri. They state that puriri gives rise to the most fertile soils for a given parent material. It appears from the foregoing that the indigenous large-leaved dicotyledons in general produce a litter of high base status.

The distribution of the exchangeable bases* in profiles 1 and 2 (Tables II and III) is indicative of the favourable balance existing between the loss and return of bases in this soil type. The satisfactory base status of the soil under the bush at Aokautere (Table IV) is further evidence of the fertility engendered by the forest cover.

The high Mg/Ca ratio found throughout the profiles has, according to Dixon (private communication) been noted for other yellow-grey loams.

While, as far as could be ascertained, no lime had been applied to the area from which the Massey College soils were taken, it was impossible to obtain incontrovertible evidence on this point. The site at Aokautere was therefore selected as being definitely free from such influence. Samples K 1, 2, 3, 4 (Table IV) were taken from positions under the bush carrying a forest litter, and the Mg/Ca ratios in these soils closely resemble those found at Massey College. The remaining Aokautere soils also exhibit a similar Mg/Ca ratio, even though the individual amounts of these bases vary within wide limits.

Samples K 6 and K 8 from Aokautere (Table IV) were obtained from positions resembling the profile sites at Massey College. Sample K 7 was taken from a position which had remained damp throughout an exceptionally dry summer. The soil in this position was characterized by rusty staining right up to the surface. Samples K 9, 10, 11, 12 were obtained from unploughed land away from the bush carrying a surface-sown pasture and an abundance of rushes (Fig. 2). It is not precisely known for how long the bush has been cleared from this area, but fifty years may be taken as the approximate period. It will be noted that these four samples possess a low exchangeable base content, a low exchange capacity, and a low saturation in comparison with the soils still influenced by bush. Comber's(11) test for lime requirement seems to correlate satisfactorily with the base saturation on this soil type, and exploratory work with the aid of this test at Aokautere and on unploughed and unlimed land near Massey College indicates that soils from which the bush has been cleared for a considerable number of years show a general increase in unsaturation. A base saturation of over 60 per cent. is commonly regarded as an indication of a fertile soil. On the evidence available it would appear that the soil type under consideration is, on the average, adequately saturated at the time of removal of the bush, quite apart from the increment of bases received as a result of the bush burn, whereas 40 per cent. seems to represent the average saturation in the top 4 in. or 5 in. on unploughed and unlimed land which has been surface sown following the original bush burn. A definite lime response is observable on these pastures. No chemical studies have been made on profiles away from the bush, but the comparatively low figures for the individual bases in samples K 9, 10, 11, 12 point to considerable losses of calcium and magnesium from the surface soil. It is reported(12) with reference to the soils of Hawke's Bay that " the forest humus raises the fertility above that of soils formed under light scrub vegetation, but the advantage of a former forest cover

* Neutral N—ammonium acetate was employed as the leaching agent in the determination of exchangeable calcium and magnesium. The total exchangeable bases were determined on the ammonium acetate leachate by the method of Bray and Willhite(9). Parker's barium acetate method(10) was employed for the determination of exchangeable hydrogen.

does not last more than fifteen or twenty years." On the basis of the limited evidence available, this appears to be substantially true for the soils under consideration.

(v) *Nutrient Status.*—No citric-soluble potash and phosphate determinations have been carried out, but use has been made of Spurway's method(13) for a rapid assessment of available plant nutrients. Dixon and Metson(14) have found a high correlation between the results obtained by a semi-quantitative modification of this method and citric-soluble potash for many New Zealand soils. All of the forest soils examined in the course of the present work are well supplied with potash in the surface horizon.

FIG. 2.—The site from which the Aokautere samples were taken.

The potash status of soils uninfluenced by bush for the past fifty years or so is lower, but generally still adequate. The available phosphate status of the surface soils from under bush varies from moderate to low, whereas that of the soils away from the bush is generally low.

(vi) *Composition of the Clay Fraction.*—The analyses of the clay fractions from profile 1 are presented in Table V. Iron has been lost from the clay fraction in the A horizon, and the trend in the Al_2O_3/Fe_2O_3 ratio shows that iron has been affected to a greater extent than alumina. The data do not, however, permit a decision to be reached as to whether alumina has moved in the profile ; the clay fraction in the parent material is more siliceous than that in the A and B horizons, and it is not known whether the minimum value attained by the SiO_2/Al_2O_3 ratio in the B horizon reflects an accession of alumina or a relatively greater loss of silica from the clay fraction in this portion of the profile.

TABLE IV.—BASE STATUS, REACTION, AND LOSS ON IGNITION FOR TWELVE SOILS FROM AOKAUTERE (Sampling depth, 0 in. to $4\frac{1}{2}$ in.)

Soil No.	Description of Site.	Exchangeable Cations.			Total Exchangeable Bases.	Proportion of Total Bases present as—		Exchange Capacity.	Base Saturation.	pH.	Loss on Ignition
		Ca.	Mg.	H.		Ca.	Mg.				
		m.e. per Cent.	m.e. per Cent.	m.e. per Cent.	m.e. per Cent.	Per Cent.	Per Cent.	m.e. per Cent.	Per Cent.		Per Cent.
K1	Under rain forest. Litter present	9·9	4·4	7·7	16·3	61	27	24·0	68	6·1	12·8
K2		16·4	7·0	8·2	26·8	61	26	35·0	77	6·3	17·5
K3		9·2	3·9	9·1	14·2	65	27	23·3	61	5·9	13·1
K4		15·6	5·9	8·9	23·2	67	25	32·1	72	6·3	15·4
K5		..	..	11·3	10·4	..	..	21·7	48	5·9	10·5
K6	Under trees. Surface-sown pasture present	17·2	3·8	8·8	22·3	77	17	31·1	72	6·6	14·2
K7	Poorly drained position carrying surface-sown pasture and scrubby bush. No large forest trees in immediate vicinity	2·8	1·1	11·7	3·9	72	28	15·6	25	5·3	9·5
K8	Open bush. Surface-sown pasture present. Similar to profile sites at Massey College	11·3	4·8	8·6	16·7	68	29	25·3	66	6·4	12·0
K9	Uncultivated land, away from bush, carrying surface-sown pasture. Rushes abundant	4·2	1·6	9·2	5·7	72	28	14·9	38	5·6	10·8
K10		3·8	1·7	12·3	5·7	67	30	18·0	32	5·3	13·7
K11		5·1	2·3	10·4	7·4	69	31	17·8	42	5·5	13·8
K12		5·3	1·9	8·9	7·1	74	26	16·0	44	5·7	11·0

TABLE V.—COMPOSITION* OF CLAY FRACTIONS FROM PROFILE 1

Horizon.	Depth.	SiO_2.	Al_2O_3.	Fe_2O_3.	TiO_2.	Molecular Ratios.			
						$\frac{SiO_2}{Al_2O_3+Fe_2O_3}$	$\frac{SiO_2}{Al_2O_3}$	$\frac{Al_2O_3}{Fe_2O_3}$	$\frac{SiO_2}{Fe_2O_3}$
	In.	Per Cent.	Per Cent.	Per Cent.	Per Cent.				
A	0–$4\frac{1}{2}$	58·02	31·00	9·52	1·46	2·66	3·18	5·10	16·22
A–B	$4\frac{1}{2}$–11	55·50	32·30	10·64	1·56	2·32	2·92	4·76	13·90
B	11–17	53·89	31·55	13·03	1·53	2·29	2·89	3·80	10·98
B	17–23	54·02	30·38	14·00	1·60	2·33	3·02	3·40	10·27
B–C	23–30	56·91	28·25	13·25	1·59	2·63	3·42	3·34	11·42
C	30–34	56·96	27·55	13·93	1·56	2·65	3·51	3·10	10·88
C	34–38	57·18	27·70	13·62	1·50	2·67	3·50	3·19	11·17
C	38–42	57·81	27·18	13·50	1·51	2·74	3·61	3·17	11·39
C	42–46	57·88	27·13	13·49	1·50	2·76	3·62	3·15	11·41

* Composition expressed as percentages of amounts of constituents determined.

NOTE.—The clay fractions were prepared using a time-depth ratio of 8·6 cm./24 hours.

(vii) *Free Sesquioxides.*—Table VI shows the amounts of free sesquioxides extracted in different parts of profile 1 by Tamm's(15) acid oxalate solution. While the soil under consideration is admittedly too heavy to give very reliable values with this method, the results obtained may be regarded as providing some information concerning the relative distribution of free iron and alumina throughout the profile. Viewed in conjunction with the observations made on the colour of the R_2O_3 precipitate, the figures show that more free alumina is present in the A horizon than in the B, suggesting that there is no marked tendency for alumina to move downwards. The virtual constancy in the total amounts of free sesquioxides extracted throughout the depth of the solum does not represent the true position with respect to iron. As will be shown, considerable amounts of free iron are segregated in the concretionary ironstone present in the B horizon, and the bulk of this has been removed from the soil prior to analysis. Furthermore, the smaller ironstone granules which pass the 2 mm. sieve will for the most part be only superficially attacked by the oxalate solution on account of their induration. Were this segregated iron to be included, the free iron content of the B horizon would be very considerably augmented.

Table VI also furnishes further evidence for the lower limit of the B horizon.

(viii) *Concretionary Iron.*—A limited study has been made of the concretionary material present in the soils under investigation. As was indicated in the profile descriptions, the concretions are concentrated mainly in the upper B horizon, although they occur also to some extent in the A–B horizon. The lower portion of the B horizon contains small pin-head size concretions only, while below this depth there is no concretionary development. The amount of concretionary material varies considerably in different profiles, but in all cases the zone of maximum incidence appears to be the upper B horizon. For the most part the concretions are well cemented and difficult to crush, but soft weakly cemented concretions also occur. The exterior surfaces are generally rusty-brown in colour, but the interiors are frequently darker. In Table VII the composition of the ironstone concretions above 2 mm. in diameter from the 11 in. to 17 in. layer of profile 1 is compared with the composition of the soil from which they were separated.* The free iron content of the concretionary material determined by the sulphide method(16) is also included in Table VII. The analyses reveal a large concentration of iron in the concretions, mainly in the form of free iron oxide, as might be anticipated from their appearance. The commonly associated segregation of manganese is also evident, but the amount present in the concretions is small in comparison with many of the values reported by other workers (17, 18). Table VII also indicates a higher concentration of phosphate in the concretions than in the soil. Wheeting(19) has remarked on the enrichment in phosphorus of the iron pellets found in the so-called "shot" soils of Western Washington. The higher loss on ignition found for the concretionary material probably represents water associated with the Fe_2O_3, as there does not seem to be any enrichment in humus.

The free iron concentrated in the concretions has probably been largely derived from the surface horizon, for, while the clay analyses point to a considerable segregation of iron from the clay fraction in this portion of the profile, the colour of the soil and Tamm's acid oxalate extraction show that there has been very little accumulation of free iron oxide.

* The coarse sand fraction, which consisted almost entirely of small concretions, was removed from the soil by wet sieving prior to analysis. The concretions removed by the 2 mm. sieve were "cleaned" by shaking with dilute ammonia solution.

TABLE VI.—FREE SESQUIOXIDES EXTRACTED FROM PROFILE 1 BY TAMM'S ACID OXALATE SOLUTION (pH 3·25)

Soil No.	Horizon.	Depth.	$Fe_2O_3+Al_2O_3$.	Comments.
		In.	Per Cent.	
T 156 ..	A	0–4½	0·88	The ammonia precipitate was practically colourless for the 0 in. to 4½ in. layer. The colour became progressively stronger for the succeeding layers, and reached a maximum intensity for the 17 in. to 23 in. layer. Thus, although the total amounts of sesquioxides extracted were virtually constant throughout the depth of 0 in. to 23 in., the ratio Fe_2O_3/Al_2O_3 steadily increased.
T 157 ..	A–B	4½–11	0·86	
T 158 ..	B	11–17	0·98	
T 159 ..	B	17–23	0·82	
T 160 ..	B–C	23–30	0·30	The ammonia precipitate showed a sharp change in colour for the 23 in. to 30 in. layer and appeared to be almost free of $Fe(OH)_3$. The precipitate for the 30 in. to 34 in. was only slightly coloured by $Fe(OH)_3$.
T 161 ..	C	30–34	0·42	

TABLE VII.—COMPOSITION OF THE CONCRETIONARY MATERIAL COMPARED WITH THE COMPOSITION OF THE CONCRETION-FREED SOIL

Soil No.	——	Loss on Ignition	SiO_2.	Al_2O_3.	Fe_2O_3.	TiO_2.	P_2O_5.	MnO.	Total.	Free Fe_2O_3.
		Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
T 158..	Concretions	7·51	45·05	10·36	31·67	0·44	0·14	0·20	95·37	27·4
	Soil ..	4·85	72·32	13·15	3·49	0·49	0·07	0·02	94·39	..

TABLE VIII.—PARTIAL ANALYSIS OF IGNITED WHOLE SOIL FROM PROFILE 1, INCLUSIVE OF CONCRETIONARY MATERIAL

Soil No.	Horizon.	Depth.	SiO_2.	Al_2O_3.	Fe_2O_3.	TiO_2.	P_2O_5.	MnO.	Total.	Molecular Ratios.			
										$\frac{SiO_2}{R_2O_3}$	$\frac{SiO_2}{Al_2O_3}$	$\frac{SiO_2}{Fe_2O_3}$	$\frac{Al_2O_3}{Fe_2O_3}$
		In.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.				
T 156	A	0–4½	75·59	13·67	2·92	0·49	0·36	0·14	93·17	8·26	9·24	68·82	7·45
T 157	A–B	4½–11	75·81	13·90	3·27	0·49	0·16	0·03	93·66	8·05	9·26	61·65	6·66
T 158	B	11–17	75·23	13·79	4·73	0·48	0·08	0·03	94·34	7·60	9·26	42·29	4·57
T 159	B	17–23	74·08	15·10	4·42	0·59	0·05	0·02	94·26	7·02	8·33	44·56	5·35
T 160	B–C	23–30	74·10	15·44	3·85	0·61	0·05	0·02	94·07	7·03	8·15	51·17	6·28
T 161	C	30–34	73·50	15·66	4·06	0·64	0·06	0·02	93·94	6·83	7·97	48·15	6·04

Although some concretions have formed in all profiles, the strongest development occurs in localized patches. These positions have possibly been enriched by iron compounds brought in by lateral movement of water in the soil, a process on which the distribution of forest trees may have had considerable bearing. It is of interest to note that on steeply sloping ground, at the heads and sides of gullies to which water seeps freely, massive deposits of ironstone are frequently encountered.

(ix) *Composition of Whole Soil.*—A partial analysis of the whole soil from profile 1 is presented in Table VIII. The downward movement of iron is shown by the minimum values attained by the SiO_2/Fe_2O_3 and the Al_2O_3/Fe_2O_3 ratios in the B horizon, while the relative immobility of alumina is indicated by the decrease in the Al_2O_3/Fe_2O_3 ratio throughout the solum.

On the assumption that the parent alluvium was of uniform chemical composition, the constancy of the SiO_2/Al_2O_3 ratio throughout the depth 0 in. to 17 in. indicates that relative movement of silica and alumina in this part of the profile has been insufficient to produce any significant differences in the composition of the whole soil. The slight fall-off in this ratio which occurs in the lower B horizon continues into the C horizon, although the clay content, as indicated by the mechanical analysis, is decreasing at this depth. The trend in the ratio in the lower portion of the profile is probably due to differences in composition of the original alluvium, in which case the slight fall-off in the ratio in the lower B horizon does not necessarily result from the illuviation of colloidal material from the upper horizons. It seems more probable that the development of the textural profile is dependent chiefly upon the formation of secondary clay in place.

ACKNOWLEDGMENTS

Grateful acknowledgment is made to Dr. J. K. Dixon and Mr. H. S. Gibbs, of the Soil Survey Division, Department of Scientific and Industrial Research, and to Mr. A. W. Hudson, of Massey Agricultural College, for valuable criticism and advice.

REFERENCES

(1) GRANGE, L. I. (1941): *N.Z. Dept. Sci. and Ind. Res. Ann. Rep.*, p. 29.
(2) MORGAN, P. G. (1922–23): *N.Z. J. Sci. and Tech.*, *5*, 46–7.
(3) ASTON, B. C. (1920): *N.Z. J. Agr.*, *21*, 105–114.
(4) GRANGE, L. I. (1941): *N.Z. Dept. Sci. & Ind. Res. Ann. Rep.*, p. 30.
(5) HUDSON, A. W., and FIFE, C. V. (1940): *N.Z. J. Sci. & Tech.*, *22*, 197A–208A.
(6) ASTON, B. C. (1920): *N.Z. J. Agr.*, *21*, 105–114.
(7) THOMSON, J. S., and SIMPSON, G. (1936): *Trans. Roy. Soc. N.Z.*, *66*, 192–200.
(8) TAYLOR, N. H., and DIXON, J. K. (1938): *N.Z. Dept. Sci. & Ind. Res. Ann. Rep.*, p. 58.
(9) BRAY, R. H., and WILLHITE, F. M. (1929): *Ind. Eng. Chem. (Anal. Ed.)*, *1*, 144.
(10) PARKER, F. W. (1929): *J. Am. Soc. Agron.*, *21*, 1030–39.
(11) COMBER, N. M. (1920): *J. Agr. Sci.*, *10*, 420–4.
(12) GRANGE, L. I. (1937): *N.Z. Dept. Sci. & Ind. Res. Ann. Rep.*, p. 61.
(13) SPURWAY, C. H. (1938): *Tech. Bull. 132*, Mich. Agr. Exp. Sta.
(14) DIXON, J. K., and METSON, A. J. (1939): *N.Z. J. Sci. & Tech.*, *20*, 404A–409A.
(15) TAMM, O. (1922): *Medd. fr. Statens. Skogsforsoksanstalt*, *19*, 387–404.
(16) TROUG, E., *et. al.* (1936): *Proc. Soil Sci. Soc. Am.*, *1*, 101–113.
(17) DROSDOFF, M., and NIKIFOROFF, C. C. (1940): *Soil Sci.*, *49*, 333–45.
(18) WINTERS, E. (1938): *Soil Sci.*, *46*, 33–40.
(19) WHEETING, L. C. (1936): *Soil Sci.*, *41*, 35–45.

A TRAP FOR COLLECTING ADULTS OF GROUND-PUPATING INSECTS

By J. M. KELSEY, Assistant Entomologist, Cawthron Institute, Nelson

[*Received for publication, 17th August, 1944*]

THOUGH the simple trap arrangement described below has been tested for only three insects, the writer is convinced that it will prove to be equally successful with other insects with similar habits. Initially the apparatus was worked out for facilitating the collection of the Chilean sawfly *Antholcus varinervis*, which was introduced to New Zealand by the Cawthron Institute to control the seeding of our noxious weed piri piri (*Acaena sanguisorbiae*), but since then the trap has been used to collect the bronze beetle *Eucolaspis brunneus*, and one of our grass grub beetles, *Odontria zealandica*, from soil

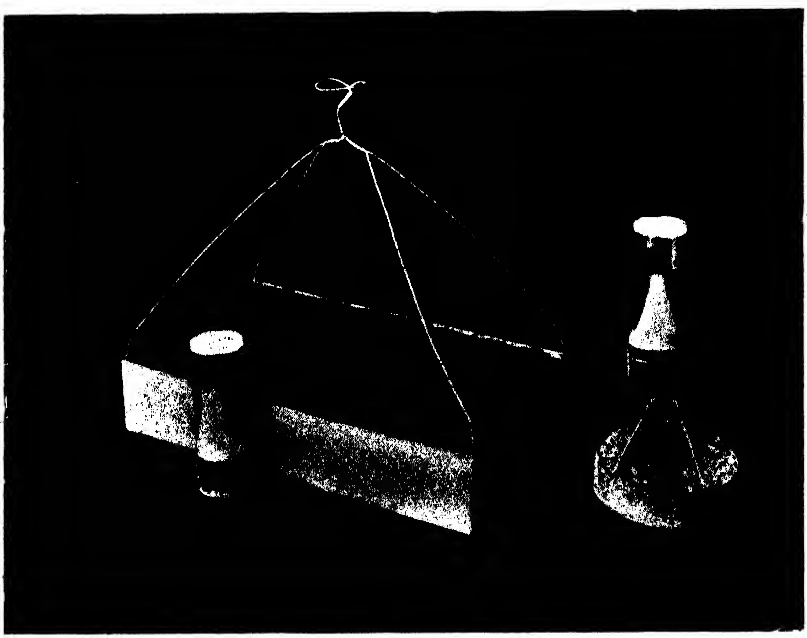


FIG. 1.

removed from the field and placed in the soil containers of the trap. In addition, the grass grub beetle was captured in a modification of this trap using a bottomless soil container as a sort of open box placed on ground infested by the beetle larvæ. In this latter case greatest success was attained only when the grass was closely clipped, and even then many beetles flew off the wires, &c., before reaching the actual trap. A point that is significant in this connection is that the lowest traps to the ground collected the most beetles. The bronze beetle is more readily trapped than that of the grass grub, very few beetles escaping the traps.

Of the large numbers of *Antholcus* emerging at the time this trap was evolved, only about eight were found on the outside of the traps, and these cases were due to the celluloid traps tilting on the wire loops so that their bases rested against the vertical wires, thus allowing the sawflies to crawl up the outside of the traps.

The apparatus is easily adjusted to fit any size or shape of container, and the handling of the insects is reduced to a minimum, so avoiding possible injury. The celluloid trap may be changed rapidly and made in any desired size. It has the added advantage that it is cheap to make. For its efficient working its only requirement is that the insects should be negatively geotropic in the adult state, and this is a phenomenon exhibited by the vast majority of ground-pupating insects. The length of time immediately after the adults emerge from the soil, and before they fly, is important, for if this period is very short the insects may fly before reaching the actual trap, as appeared to be the case with some of the grass grub beetles mentioned above.

At the Cawthron Institute, Nelson, the traps were housed inside a framework of wood, glass, and muslin inside a gauze-lined insectary as seen in Fig. 2, but for certain insects the apparatus may be used out in the open field, though best results appear to be obtained indoors. As will be seen

FIG. 2.

from an inspection of Fig. 1, there is absolutely nothing to prevent the insects from flying off the wires, &c., except for the fact that this type of insect after leaving the soil climbs up any adjacent object in order to permit its wings to unfold and harden, and it was the fact that all emerging sawflies were found on top of the highest soil humps, &c., that led to the construction of this trap.

The actual trap part of the apparatus was made by Mr. C. H. G. Fraser, of the Cawthron staff, the writer adapting the rest of the apparatus to fit these traps.

The parts of the trap can be seen in Figs. 1 and 2. Figure 3 gives the apparatus in diagrammatic form. "A" is the soil container in which the insects have pupated; it is filled to within $\frac{1}{4}$ in. or $\frac{1}{2}$ in. of the top and is raised at least 1 in. above the surrounding soil so that emerging insects climb on to the rim of the container. The wires "B" are

soft galvanized wire of light gauge, and preferably rough to the feel to afford good foothold; there are four wires, two of which are longer than the others to form the loop and vertical pieces. These two wires are twisted round one another about five times at point "C," and the longer wire bent up to form the vertical piece "D," the angled piece "E," and the loop "F," so that the vertical piece "D" comes to lie below the centre of the loop. The wire is twisted to prevent the loop opening. Parts "G–J"

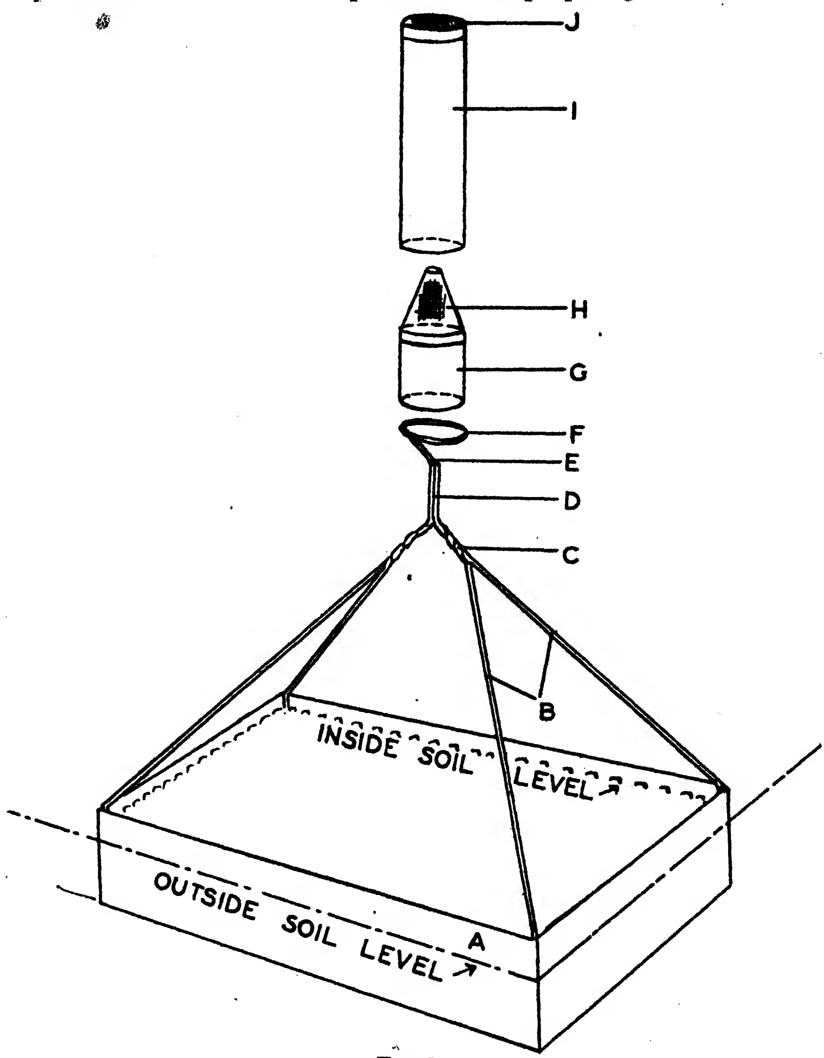


FIG. 3.

are made of celluloid and muslin cemented together with celluloid dissolved in amyl acetate or acetone. "G" is a very slightly tapering celluloid collar to which is cemented the muslin cone "H" to prevent trapped insects from returning once they have entered the trap. This collar and cone fit tightly into the celluloid cylinder "I," which is fitted with a muslin top "J."

It was found best to make the cone and top of the trap of muslin so as to allow a free circulation of air to prevent condensation of moisture on the cylinder walls when it contained insects.

Points to remember are to have sufficient clearance between the bottom of the trap collar and the wire shoulders at " C " to prevent insects climbing from the wires here to the outside of the cage, and to see that the wire loop fits tightly inside the collar, otherwise the trap may tilt against the piece " D."

The maximum size of container used was 12 in. by 6 in. by 2 in. with the wire loop about 6 in. above the container; the trap was a cylinder 6 in. long by 1 in. in diameter. The smallest containers were round 2 oz. tobacco-tins, as seen to the right in Fig. 1.

ACKNOWLEDGMENTS

Acknowledgments are due to Mr. W. C. Davies, of the Cawthron Institute, for the excellent photographs in Figs. 1 and 2.

THE VALUE OF VITAMIN A SUPPLEMENTS TO PIGS FATTENED ON BUTTERMILK

By C. E. BALLINGER, Research Officer in Animal Nutrition, Ruakura Animal Research Station, Department of Agriculture

[*Received for publication, 24th August, 1944*]

Summary

The effect of feeding a vitamin A concentrate with a ration of maize and meat-meal to store pigs for thirteen weeks, and subsequently with a fattening ration of buttermilk, has been investigated.

Mean values for the vitamin A content of the pigs' livers showed a difference in keeping with the quantity of vitamin A fed to the pigs.

No significant differences between groups in their rate of growth as store pigs or utilization of the fattening ration as baconers was obtained. No symptoms of vitamin A deficiency were seen.

IN New Zealand a considerable amount of bacon is produced from pigs born in the autumn and held in store condition until the spring, when they are fattened on dairy by-products. The treatment of the store pigs during the winter varies from running them in the cow paddocks to confining them to sties or to pens devoid of pasture.

The winter ration may consist of roots, maize, or small quantities of meals, and dairy by-products. In many instances the pigs do not have access to pasture and are fed a ration low in vitamin A—*e.g.*, maize- and meat-meal or separated milk. Such pigs may be retained under these conditions for about three months, and then be sold for fattening on buttermilk. During the fattening period the pigs may again be retained in sties or pens devoid of grass.

Under the circumstances the ration may be low in vitamin A for five or six months, and it is considered possible that, while no obvious symptom of vitamin A deficiency appears, there might be unthriftiness in the latter stages of fattening and poor utilization of the fattening ration.

Previous work on this problem(1) has shown that store pigs living on a ration low in vitamin A and confined to bare yards for three months, while not showing symptoms of vitamin A deficiency, did show a lower vitamin content of their livers compared with pigs run on pasture. It was also found that pigs running on pasture did not benefit by feeding a vitamin A concentrate, although they accumulated a reserve of vitamin A in the liver more than three times as great as pigs not receiving the vitamin supplement.

The literature on the vitamin A requirements of pigs has been dealt with in a previous paper(1). The possibility of a vitamin deficiency in pigs wintered in store condition on yards devoid of pasture and subsequently fattened on buttermilk was pointed out in that work, and the results presented in this paper conclude the investigation.

AIM OF THE PROJECT

In order to explore the possibility of pigs benefiting by the feeding of vitamin A in the fattening stages it was decided to place three groups each of twelve pigs on a basic ration of maize- and meat-meal for a period of three months, to be followed by fattening to bacon weights on buttermilk. The pigs were run in dirt yards devoid of pasture. Prior to going on trial the pigs were kept under open-air conditions with access to good pasture until they were about three months old and were comparable in all respects to pigs used in the investigation into vitamin supplements already referred to.

In order to examine the possible benefit of the addition of vitamin A to the ration, three groups received the following treatments:—

—	Treatments.	
	Store Period.	Fattening Period.
Group 1 (control)	Basic ration	Buttermilk.
Group 2	Basic ration + vitamin A	Buttermilk.
Group 3	Basic ration + vitamin A	Buttermilk + vitamin A.

The vitamin A was given at the rate of 9,000 I.U. per head per day.

EXPERIMENTAL RESULTS

Progress over the Store Period.—The progress of the groups over a thirteen weeks' store period prior to fattening is seen in Table 1.

TABLE 1.—LIVE-WEIGHT INCREASE DURING THE STORE PERIOD IN BASIC RATION AND VITAMIN A CONCENTRATE

—	Group Nos.		
	1.	2.	3.
Number of pigs at start	12	12	12
Number of pigs at finish	11	12	12
Mean initial weight (lb.)	63·0*	62·25	61·91
Mean final weight (lb.)	99·72*	98·91	102·75
Mean increase live-weight (lb.)	36·72*	36·66	41·84
Mean increase per pig per day (lb.)	0·40*	0·40	0·45

* Calculation on the eleven pig basis.

The live-weight differences between the groups are not significant. One pig was withdrawn from group 1 after three weeks on trial, suffering from necrotic enteritis, otherwise behaviour was normal and the live-weight gains were similar to those obtained in previous years.

Progress over the Fattening Period.—At the termination of the store period the groups were retained in yards devoid of pasture and placed on a fattening ration of buttermilk at the rate of 6 gallons per pig per day. The pigs were withdrawn for slaughter when they reached approximately 200 lb. live-weight. Table 2 gives the progress of the groups over the fattening period as shown by the live-weight gain, the food to produce 1 lb. of carcass, and the mean vitamin values of the liver for the respective groups.

TABLE 2.—LIVE-WEIGHT INCREASE DURING THE FATTENING PERIOD ON BUTTERMILK AND VITAMIN A CONCENTRATE

—	Group Nos.		
	1.	2.	3.
Number of pigs at start	11	12	12
Number of pigs at finish	11	12	12
Mean initial weight (lb.)	99·72	98·91	102·75
Mean final weight (lb.)	201·81	201·66	199·91
Mean increase live-weight (lb.)	102·09 ± 13·7	102·75 ± 26·3	97·16 ± 14·7
Mean increase per pig per day (lb.)	0·96	0·92	0·94
Number of gallons buttermilk to produce 1 lb. of carcass	8·12	8·60	8·15
Mean vitamin A content per liver (grams) ..	0·0684	0·1274	0·1674

* Calculated by assuming the nitia carcass weight at 72 per cent. of the initial live-weight(2).

DISCUSSION

It appears that the addition of vitamin A to the ration has not had any effect under the conditions imposed. No symptoms of vitamin deficiency were seen, and the rate of growth for the three groups over the fattening period does not show any significant difference in favour of groups 2 and 3 compared with group 1. Since all groups were on a standard ration of 6 gallons of buttermilk per pig per day, it is also obvious that utilization and conversion of food has not been effected by the addition of vitamin A to the ration over the fattening period.

The liver values show an increased vitamin A content in keeping with the amount of vitamin A fed during the trial, but the control group shows a good reserve of vitamin A in their livers, so it would appear that pigs reared under open-air conditions with access to pasture until they are about 60 lb. live-weight do not benefit by the addition of vitamin A concentrate to a store ration of maize-meal and meat-meal, or to a fattening ration of buttermilk.

The efficiency of food-conversion in all three groups is very poor.

Under good open-air conditions with access to pasture, store pigs of the weight used in this trial require about 6·6 gallons of buttermilk to produce 1 lb. of carcass. Unfavourable conditions can therefore necessitate an extra 20 per cent. of food to fatten pigs from stores to baconers(5).

A point which should be stressed in connection with this investigation is that, although these results and previous work on store pigs show no benefit was derived from vitamin A supplements, it does not follow that vitamin A supplements are unnecessary in all circumstances. The pigs used in this work had access to good pasture from birth until they were about three months old, when they went on trial. Many pigs in New Zealand are born and reared in sties or have yards devoid of pasture. Under such circumstances pigs would most probably benefit by the addition of vitamin A to rations similar to those used in this investigation. Investigations by overseas workers on the vitamin requirements of pigs substantiate this opinion. The work of Dunlop(3, 4) in particular has shown that where pigs are confined to sties from birth without access to pasture vitamin A deficiency does occur on rations commonly fed under practical conditions.

ACKNOWLEDGMENTS

The writer wishes to express thanks to Mr. M. R. Coup, of the Chemistry Section, for the vitamin A estimation of the pigs' livers.

REFERENCES

(1) BALLINGER, C. E. (1944): *N.Z. J. Sci. & Tech. A*, *24*, 263–272.
(2) ——— (1939): *N.Z. J. Sci. & Tech. A*, *21*, 175–178.
(3) DUNLOP, S. (1934): *J. Agr. Sci.*, *24*, 435.
(4) ——— (1935): *J. Agr. Sci.*, *25*, 217.
(5) BALLINGER, C. E. (1944): Unpublished data.

THE NEW ZEALAND

JOURNAL OF SCIENCE AND TECHNOLOGY

Editor: D. Cairns, M.Sc., Department of Scientific and Industrial Research, Wellington

VOL. 26, SEC. A — APRIL, 1945 — NUMBER 6

SOIL-CONSERVATION STUDIES APPLIED TO FARMING IN HAWKE'S BAY

PART I.—INVESTIGATIONS INTO RUN-OFF AND SOIL LOSS

By D. A. CAMPBELL, Technical Officer, Soil Conservation and Rivers Control Council, Wellington

[*Received for publication, 16th November, 1944*]

Summary

The factors influencing surface run-off and soil loss were investigated, with the following results :—

Measured surface losses of water and soil from plots were comparable with losses under similar conditions in the United States of America. Losses increase progressively from negligible proportions in forest, to become very significant under continuous cultivation.

Duration of Rain.—Soil loss attains its maximum in ten to thirty minutes and declines, while run-off increases rapidly for the first half-hour and progressively more slowly thereafter.

Vegetation.—Climax native vegetation dominates all other factors and reduces losses to zero. Pasture management is a critical factor in governing losses of soil and water, as the line of demarcation between effective and non-effective cover is controlled by management.

Intensity of Rain.—This proved to be one of the most important factors in governing run-off and soil loss from eroded and farmed land.

Slope.—Increase in slope results in run-off attaining its maximum more rapidly, while soil loss increases significantly. Slopes previously protected by native vegetation are in many cases no longer sufficiently protected and create an increasing erosion hazard.

Soil Type.—Field trials demonstrate the individual behaviour of various soil types with respect to surface losses of soil and water.

Air Content.—The high air content of unfarmed soils indicates conditions that are conducive to the rapid movement of water into and through them.

Organic Matter and Water Content.—Comparative estimations (based on loss on ignition for the former) show that eroded soils have a lower content of these.

Soil Structure.—Soil aggregates diminish in size and stability as a result of cultivation and severe grazing.

Water-holding Capacity.—Undisturbed soils contrast sharply with farmed soils in ability to hold water, but the inherent ability to hold water cannot always be availed of under farmed conditions.

Litter and Roots.—When the influence of litter and roots is removed and the soil consolidated to destroy structure, forest soils become similar in reaction to cultivated soils. The absorptive capacity of forest litter is not sufficient to account for its high rate of infiltration.

Burning.—Considerable increases in run-off and soil loss are induced by burning the vegetative cover.

Consolidation.—Tramping by stock has proved to be one of the most potent factors in increasing losses of soil and water.

Cultivation.—The greatest losses of soil and water by surface run-off were obtained from cultivated soils, particularly those under continuous cultivation.

Infiltration.—The considerable variation in rates between farmed and unfarmed soils is consistent with the general findings and has a high degree of correlation with several of the above factors.

Interception of Rain by Plants.—Plants intercept and bring under their control a large proportion of the rain falling on them and conduct much of it into the soil by way of their stems and roots. Plants play a very active role in buffering the force of the rain and in conducting it directly to the deeper soil horizons.

The changes wrought by man that have impaired the resistance of soils to erosion can be measured in several ways. Comparative studies in run-off and soil loss provide a suitable and practical measure of these changes for an experimental approach to the problem.

INTRODUCTION

FROM observation in Hawke's Bay in respect to land deterioration, declining productivity, and the increase of severely eroded areas it seemed imperative to investigate the various aspects of the problem. In the first instance it was necessary to establish the actual surface losses of water and soil taking place and the factors influencing the extent of these losses. This critical information was then applied to the investigation of changes brought about as a result of farming practices. The possibilities of revegetation of eroded areas were then investigated in various localities. From the results of these specific investigations an attempt is made to formulate a statement of the best methods of modifying present land use in order to conserve productivity.

INVESTIGATIONS INTO SURFACE RUN-OFF AND SOIL LOSS

As surface run-off and soil loss are conspicuous features of eroded land, the various factors influencing them were investigated under field conditions.

In order to obtain direct information to provide a basis of comparison for the discussion of artificial rain results, it was necessary to measure soil and water losses from plots under typical conditions.

Suitable sites were chosen in and near a vineyard, and plots 6 ft. by 3 ft. were enclosed by timber to prevent loss of run-off laterally and to prevent other water from running on to the plots.

At the lower end a covered collecting tray was designed to divert all run-off into a suitable collecting vessel, which was placed in an excavation. A standard rain gauge was set up in the vicinity of the plots. Similar plots were set up at Tangoio and records taken for a short period.

After each fall of rain the quantity was recorded and the run-off weighed and sampled. After drying and weighing, the soil loss was computed (Table I).

TABLE I.—RUN-OFF AND SOIL LOSS DATA

Plots at Greenmeadows on Matapiro and Crownthorpe Sandy Loams

Date recorded.	Rainfall (Inches)	Slope, 15°: Cultivated Soil.			Slope, 20°: Ungrazed Old Pasture.			Slope, 20°: Grazed Poor Pasture.		
		Run-off (lb.).	Run-off (per Cent.).	Tons per Acre Soil Loss.	Run-off (lb.).	Run-off (per Cent.).	Tons per Acre Soil Loss.	Run-off (lb.).	Run-off (per Cent.).	Tons per Acre Soil Loss.
1939										
Aug. 24 ..	0·25	..	..	..	..	..	..	..	..	..
28 ..	0·84	13	13·8	1·6	..	..	..	..	..	..
Sept. 7 ..	..	..	..	..	..	..	..	..	..	..
13 ..	0·80	4·2	5·6	0·5	..	..	..	5·5	7·3	0·25
24 ..	0·25	..	..	..	..	..	..	..	..	..
25 ..	1·15	4·1	5·5	0·27	..	..	..	16	17	0·05
Oct. 14 ..	0·41	1·5	4·0	0·13	..	..	..	2	5·3	0·02
Nov. 25 ..	0·95	30	33·7	0·90	1·9	2·3	..	38	42·7	0·11
27 ..	0·22	..	..	..	..	..	..	..	..	..
Dec. 11 ..	0·45	1	2·3	0·02	..	..	..	1·25	3·1	..
12 ..	0·37	..	..	..	..	..	..	..	..	..
26 ..	0·66	24	38·7	4·8	1·2	2·0	..	25	40·3	0·21
1940										
Jan. 13 ..	0·81	3	4·0	0·24	1·25	1·7	..	3	4·0	0·02
21 ..	0·70	3·2	4·8	0·24	0·5	0·8	..	11	16·7	0·02
Feb. 24 ..	0·50	4·2	9	0·13	..	..	..	6	13	0·07
25 ..	1·75	65	40·2	1·97	4	2·4	..	72	42·3	0·61
Mar. 9 ..	0·31	0·3	1	0·02	..	..	..	0·4	1·4	0·02
Apr. 11 ..	0·30	..	..	0·05	..	..	..	..	..	0·03
12 ..	0·33	3	9·9	0·15	..	..	..	1	3·2	0·09
13 ..	0·75	35·5	51·1	1·05	2·5	3·5	..	39	55·7	0·41
14 ..	0·14	0·5	0·4	..	..	..	..	0·5	0·4	..
19 ..	0·55	9·5	18·2	0·32	0·5	1·0	..	4·5	8·7	0·03
22 ..	0·65	18·5	30·3	0·03	0·5	0·8	..	7·5	12·3	0·01
May 12 ..	5·50	165	32·2	4·05	..	..	..	55	10·7	1·84
21 ..	0·16	1	7	0·02	..	..	..	0·5	3	0·002
23 ..	0·70	8	12·3	0·13	..	..	..	2	3	0·02
June 15 ..	0·32	2	6·2	..	..	..	..	1	3·2	0·02
July 6 ..	1·25	14·5	2·5	0·13	..	..	..	15·5	3·4	0·06
7 ..	0·15	0·75	6·6	..	..	..	..	0·25	2·2	0·002
8 ..	0·75	23·5	40·3	0·33	1·5	2·6	..	20	35·8	0·035
19 ..	0·67	16	22·5	0·64	..	..	..	12	1	0·1
27 ..	1·75	48	30	0·94	2·5	1·3	..	37	22·7	0·035
Aug. 11 ..	1·05	33	33	0·30	1	1·1	..	17	18	0·031
14 ..	1·15	43·5	40·6	0·58	1·75	1·6	..	14·5	13·5	0·32
18 ..	1·75	93	58·9	1·52	1·5	1·0	..	23	14	0·24
Totals ..	28·34	..	..	21·06	..	..	..	..	..	4·05
Averages	..	..	19·2	..	..	1·7	..	..	11·6	..

Tangoio Plots on Crownthorpe Sandy Loam

Date.	Rainfall (Inches).	Forest Floor.			Rank Pasture.		
		Run-off (lb.).	Run-off (per Cent.).	Soil Loss.	Run-off (lb.).	Run-off (per Cent.).	Soil Loss.
12/9/39	4·8	1·2	0·7	..	37·5	22·1	..
12/10/39 ..	1·42	1·1	0·8	..	27·8	20·9	..
27/11/39 ..	0·78	0·6	0·85	..	20·2	27·6	..
11/12/39 ..	0·74	0·1	0·14	..	18·6	26·8	..
12/12/39 ..	0·32	..	..	..	5·8	19·3	..
12/1/40	0·73	..	..	..	17·5	29·2	..
Averages ..	..	..	0·41	..	..	24·3	..

Plot Studies

Plot studies revealed that surface run-off and soil loss were negligible under native forest and ungrazed grassland conditions. Losses were considerable on fallow land, and intermediate in extent on grazed pasture. Although the totals indicate the annual losses, they mask the effect of individual storms, which are often very destructive. In a recent storm 3·8 in. of rain fell in two days; 41 per cent. ran off, carrying with it the equivalent of 6·4 tons per acre of soil from the fallow plot. This indicates that a single fall of rain can be responsible for most of the soil loss in a year.

Soil loss was not in simple ratio to run-off, but increased greatly during rains of high intensity. The condition of the surface of the fallow plot influenced soil losses considerably; during winter the losses were lowest from the uncultivated compacted surface, but for the remainder of the year the cultivated loose surface allowed of excessive soil loss, when there was sufficient rain to cause run-off.

The considerable loss of water from cultivated and grazed pasture plots is significant under the local conditions of a badly distributed average rainfall of 30 in. and a high rate of evaporation, and is comparable with results under similar conditions in the United States of America. The management of grassland assumes importance, as run-off and soil loss appear to increase in proportion to the severity of the grazing.

The rate of soil loss from cultivated soil is sufficient to account for the removal of 6 in. to 9 in. of topsoil from parts of the vineyard inforty years.

Equipment used: A Rain Simulator

As plot studies involve a lengthy period of observation, and sprinkler experiments on boxes of soil upset many natural factors operative under field conditions, it was urgent to evolve a practical method of simulating rainfall conditions in the field.

The advantage of such a procedure in measuring run-off and soil loss under various conditions was important, as much time and expense were saved, and urgently needed figures were obtained.

As a result of trying several types of water-distributing mechanisms, an ordinary watering-can fitted with a small nozzle which had five small apertures was found to give the best results. The quantity of water delivered could be regulated to 1 in., 1½ in., 2 in., 3 in., 4 in., and 5 in. per hour simply by plugging one or more of the apertures (the diameters varied from 0·8 mm. to 1·2 mm.). If held 5 ft. from the ground and moved by both a rotating and reciprocating motion, "rain" fell in distinct drops with momentum comparable to that of rain (as observed by the rebound and splash upon impact with the ground). This artificial "rain" was played on an area of 2 square feet, which was the optimum area when all factors were taken into consideration—varying cover types, evenness of surface, quantity of water available (this had to be transported over considerable distances), quantity of run-off and soil loss obtained, and transportability of equipment.

A collecting device was embedded in the ground on the lower side and along the lower margin of the experimental square and sealed in position with lard. The run-off was collected in a tin placed in a suitable excavation several inches away from the lower edge of the plot.

Subsequently, a rainfall simulator was fully discussed by A. L. Kennedy in *J. Am. Soc. of Agr., Engrs.*, June, 1941, and later a rainfall applicator was described by Ellison and Pomerene in *J. Am. Soc. of Agr., Engrs.*, June, 1944.

Procedure

In the first series of trials comparisons were made to test the accuracy of the mechanism, the consistency of results, regulation of intensity of "rain," and adjustment in design of the collecting mechanism. In the second series the progressive change in the rate of run-off and soil loss was studied.

In the third series of experiments 1 in. of rain was applied to varying slopes and types of cover after preliminary saturation of the soil.

In the fourth series of comparative experiments additional information was obtained with a view to correlating certain factors with erodibility.

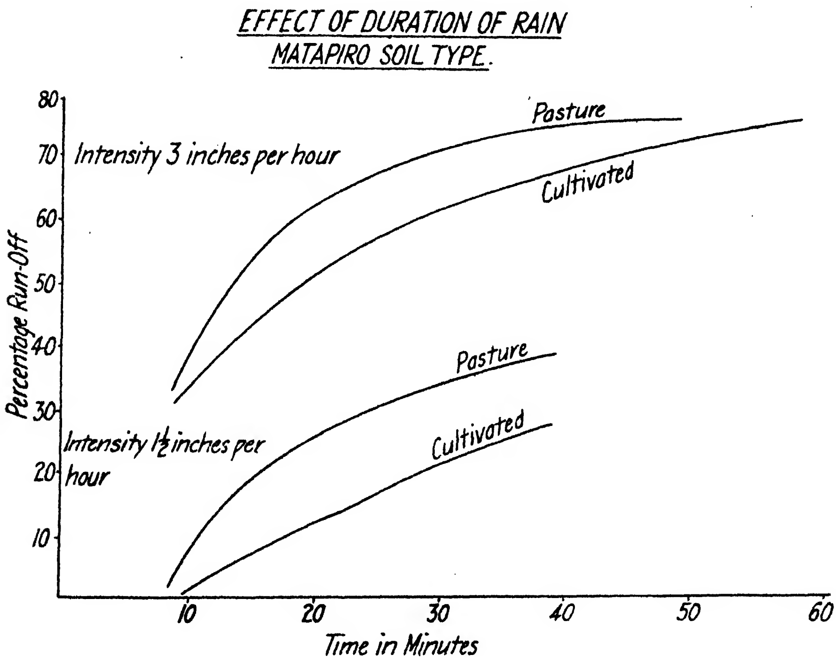


FIG. 1.

The various factors governing surface run-off and soil loss were investigated, in order to clarify the position as much as possible.

The majority of these trials were carried out after the soil had been thoroughly saturated. Great care was exercised in selecting representative situations with regard to soil type, cover, slope, &c. With the exception of boxes of soil used in Tables V and VI, all trials were carried out under field conditions with as little disturbance to the surface as possible.

DURATION OF RAIN

The rate of run-off and soil loss progressively changed during the application of rain. Analysis of run-off at intervals of ten minutes indicates that it increases rapidly in the early stages (up to fifty minutes) and very slowly thereafter (Fig. 1).

TABLE II.—THE EFFECT OF DURATION OF RAIN ON RUN-OFF AND SOIL LOSS RECORDED AT TEN-MINUTE INTERVALS ON MATAPIRO SOIL

—	Rain Intensity, 3 in. per Hour.						Rain Intensity, 1½ in. per Hour.					
	Poor Pasture.			Cultivated.			Poor Pasture.			Cultivated.		
	Replicates.	Run-off, as Percentage of Rainfall.	Soil Loss, in Tons per Acre.	Replicates.	Run-off, as Percentage of Rainfall.	Soil Loss, in Tons per Acre.	Replicates.	Run-off, as Percentage of Rainfall.	Soil Loss, in Tons per Acre.	Replicates.	Run-off, as Percentage of Rainfall.	Soil Loss, in Tons per Acre.
First ..	5	36·4	0·49	5	29·3	1·16	4	6·0	0·07	5	2·8	0·7
Second ..	5	62·7	0·94	5	51·5	2·39	4	25·7	0·25	5	11·9	0·48
Third ..	5	68·2	0·86	5	60·2	2·29	4	33·7	0·29	5	21·0	0·49
Fourth ..	5	72·7	0·80	5	68·1	2·02	4	37·6	0·26	5	27·5	0·39
Fifth ..	5	75·0	0·75	5	72·9	1·87	4	38·4	0·24	5	29·3	0·32
Sixth ..	5	79·4	1·70	5	76·3	1·70	..	..	..	..	..	..

Soil loss attains its maximum in ten to thirty minutes and declines, tending to become constant in sixty to seventy minutes. Neale(3) presents evidence in close agreement with these findings.

Owing to the fact that local floods are caused by heavy rains on saturated soils or by moderate rains of two to four days' duration, it was arranged to apply water continuously to small areas of Matapiro soil (15° slope). At convenient intervals the sprinkler was turned off and a definite quantity of water was applied to each plot with a watering-can during an interval of twenty minutes.

—	Infiltration Rates, in Inches per Hour.		
	End of First Hour.	At 48 Hour.	At 72 Hour.
Cultivated old-pasture land ..	1·1	0·39	0·21
Lightly grazed old-pasture land ..	1·5	1·11	0·89

The subsoil was very wet to a depth of 56 in. The common belief that soil becomes saturated and reduces the infiltration rate to zero in a relatively short time is not borne out by trials on this type of soil.

Projection of typical curves indicates that the infiltration rate decreases progressively more slowly as it approaches zero. In rains of long duration the rate at which infiltration approaches zero appears to be the critical factor in the incidence of flooding. This rate appears to be governed in the first instance by the original water content of the soil and condition of the surface, while the ultimate rate appears to depend on soil structure, which is largely conditioned by type of soil and vegetation.

TYPE OF VEGETATIVE COVER

The effect of vegetation on run-off and soil loss was further studied by he application of artificial rain to various plant associations.

TABLE III.—SUMMARY OF RESULTS OF 1 IN. APPLICATIONS OF RAIN TO WET SOILS UNDER VARIOUS TYPES OF VEGETATION ON FIVE MAJOR SOIL TYPES

Condition of Cover or Soil Surface.	Rainfall (Inches).	Intensity, in Inches per Hour.	Slope (°).	Run-off as Percentage of Rain.	Soil Loss, in Tons per Acre.	Number of Replicates.
Forest	1	5·0	16·4	0·34	..	24
Manuka scrub	1	3·5	20·2	0·16	..	19
Native flax	1	5·0	15·4	0·6	..	6
Tussock grassland	1·5	4·8	14·4	0·57	..	10
Bracken fern	1	3	18·4	0·55	..	24
Ungrazed grass	1	3	15	3·03	..	22
Good grazed pasture ..	1	2·74	17·4	42·2	0·034	30
Poor pasture	1	2·7	20·5	63·0	0·73	14
Eroded pasture	1	3·2	20·3	64·2	1·7	14
Completely eroded surfaces ..	1	2·9	20	66·5	6·5	16
Burnt pasture	1	3	17·5	55·5	0·65	5

FIG. 2.—Mixed podocarp forest, Ohurakura.

It was found that native associations, mixed forest, manuka scrub (*Leptospermum scoparium*) bracken fern (*Pteridium esculentum*), flax (*Phormium tenax*), and "tussock" grassland, apparently create conditions favourable to the absorption of rainfall of high intensity (from 3 in. to 4 in. per hour) (Figs. 2 and 3). As there was little or no surface run-off, losses of soil were negligible.

Ungrazed grassland prevents surface run-off and soil loss with intensities of rain up to 3 in. per hour, but losses occur from grazed pasture with intensities of less than 1 in. per hour. Poor and eroded pastures yield considerable run-off with 0·5 in. per hour of rain (Fig. 3A).

Absorption was at a minimum on eroded areas, while run-off and soil loss were at a maximum.

Run-off and soil loss on fallow land were considerable and appeared to vary according to the recency of cultivation, condition of the surface, and structure of the soil.

FIG. 3.—Tussock grassland, Kuripapanga.

As the intensities of rain used are seldom experienced, it is reasonable to assume that undamaged native plant cover creates conditions favourable to the infiltration of the heavier rains experienced under the particular local conditions. When this vegetation is destroyed or replaced by induced vegetation the reaction to rainfall is radically altered. The rate of run-off and soil loss appear to measure the extent of this change, as they are complementary to the management practised.

Grazed pasture appears to define the boundary between effective and non-effective cover in so far as run-off and soil loss are concerned, consequently pasture management becomes a critical factor in governing losses of water and soil.

The effect of soil type, intensity of rain, and slope appear to be dominated by the conditions of habitat created by native climax associations of plants.

INTENSITY OF RAIN

In order to use typical intensities of rain, records of heavy rains experienced in New Zealand were obtained from the Meteorological Office,

and it was found that intensities ranged from 0·5 in. per hour to 4 in. per hour in many storms experienced.

Over a period of twenty years sixty heavy storms were recorded. In ten of these the intensity was at least 4 in. per hour and the duration from fifteen minutes to one hour. In half the storms recorded there was a well-distributed variation of from 6 in. to 20 in. of rain in twenty-four hours. The remainder were storms of shorter duration and the intensity ranged from ½ in. to 1 in. per hour.

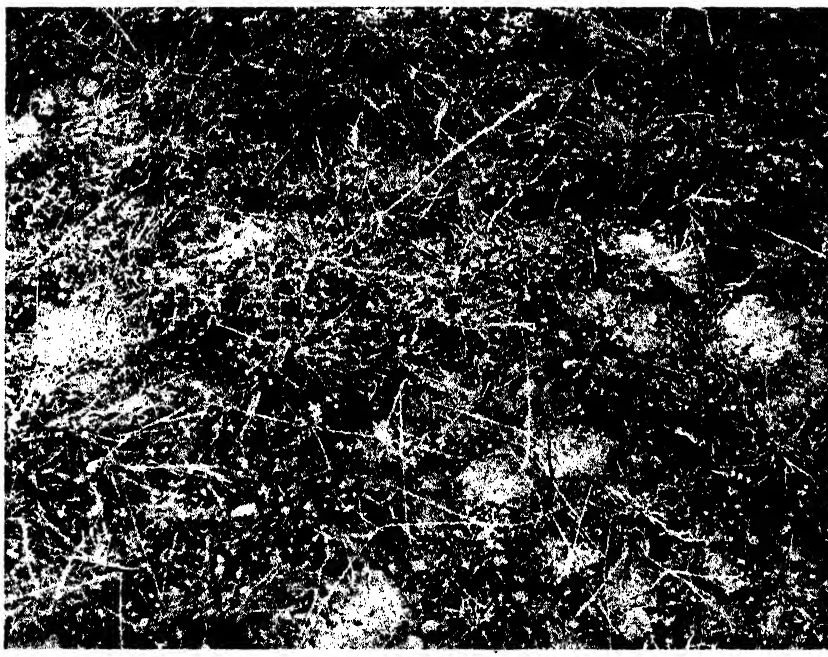


FIG. 3A.—Poor danthonia—suckling-clover pasture on a badly eroded ridge, Havelock North.

TABLE IV.—COMPARATIVE RATES OF RUN-OFF AND SOIL LOSS UNDER TWO INTENSITIES OF "RAIN"

Habitat.	Slope (°).	Intensity, 1½ in. per Hour.		Intensity, 3 in. per Hour.	
		Run-off (per Cent.).	Tons per Acre Soil Loss.	Run-off (per Cent.).	Tons per Acre Soil Loss.
Matapiro, cultivated soil ..	15	40·0	0·45	81·5	2·65
Rendzina loam, cultivated	15	15·9	0·16	51·5	1·13
Waiwhare, grazed rape ..	15	20·0	0·64	41·4	2·4
Weber, grazed rape ..	15	21·2	0·17	66·4	1·06
Gisborne sandy loam, cultivated	15	11·4	0·025	45·1	0·15
Matapiro, grazed pasture ..	15	8·9	..	42·6	..
Waiwhare, grazed pasture	25	38	..	84·0	..
Matapiro, wet cultivated soil	33	34·3	0·51	58·1	3·0
Matapiro, very wet, cultivated	33	19·4	0·83	59·9	7·6
Crownthorpe, eroded pasture	33	45·8	0·81	66·9	1·97
Waiwhare, good pasture ..	33	40·1	..	88·2	..

From trials it was found that run-off was proportional to the intensity of the rain. Soil loss was disproportionately greater during rains of high intensity owing to the rapid acceleration in carrying-capacity of the increased run-off (Ayres(4)).

It is apparent that the intensity of rain is one of the most critical factors governing run-off and soil loss from farmed and eroded land. The effect of showers of high intensity and short duration common in Hawke's Bay is significant in this connection. Neale(3) finds that rain intensity is by far the most important factor affecting run-off and soil erosion.

It was indicated in the previous section that conditions were such in climax associations that the intensities of rain likely to be experienced were adequately dealt with. This is not so on farmed land.

SLOPE

Soil samples were selected from cultivated fields representing the major soil types in Hawke's Bay. Boxes of 2 square feet in area and 12 in. deep were filled with soil, which was evenly packed. A collecting lip of lead was sealed along the lower edge and the box was inclined at the desired slope.

The soils were saturated frequently and allowed to stand several weeks in order to secure natural packing of the soil.

Prior to the commencement of the group of three trials on each slope the surface inch of soil was carefully disturbed with a small garden trowel. When the run-off and soil loss were approximately constant, water was applied from a watering-can at the rate of 4 in. per hour for twelve minutes on each box of soil at each of three different slopes.

TABLE V.—TABULATION OF TRIAL RESULTS

Soil Type.	Slope (°).	Run-off (Millilitres).	Run-off (per Cent.).	Soil Loss, in Tons per Acre.	
				Per Twelve Minutes.	Per Hour.
Matapiro cultivated for forty years	5	3,100	85·3	0·84	4·2
	15	3,160	87·0	1·36	6·8
	25	3,230	88·9	2·12	10·6
Matapiro cultivated for one year	5	3,000	82·6	0·6	3·0
	15	3,050	83·9	0·94	4·7
	25	3,105	85·3	1·30	6·5
Waiwhare cultivated one year	5	3,012	82·9	1·26	6·3
	15	3,045	83·8	2·4	12·0
	25	3,135	86·4	3·2	16·0
Gisborne sandy loam (Taupo ash)	5	1,900	52·3	1·14	5·7
	15	2,405	66·2	3·2	16·0
	25	2,455	67·5	3·72	18·6
Weber mudstone ..	5	2,780	76·5	0·44	2·2
	15	3,100	85·2	0·68	3·4
	25	3,210	88·3	0·92	4·6
Rendzina loam	5	2,800	77·0	0·60	3·0
	15	3,020	83·6	0·78	3·9
	25	3,120	85·4	1·08	9·4
Averages	5	..	76·1	0·81	4·05
	15	..	81·6	1·56	7·8
	25	..	83·6	2·05	10·25

Increase in slope did not increase run-off very significantly, but the run-off attained its maximum more quickly on the steeper slopes.

Soil loss increases significantly with increase in slope (Fig. 4). Neale(3, p. 28) in his equation shows that soil erosion is according to the 1·2 power of the slope, but this is based on more gentle slopes than were used in these trials. He states that slopes between 1° and 16° had little effect on run-off, but the relative density of the material increased with increases in slope.

The results of field trials do not agree very well with those obtained from boxes of soil set at the different slopes, owing to the change in soil type and characteristics associated with such increases in slope. The partially removed

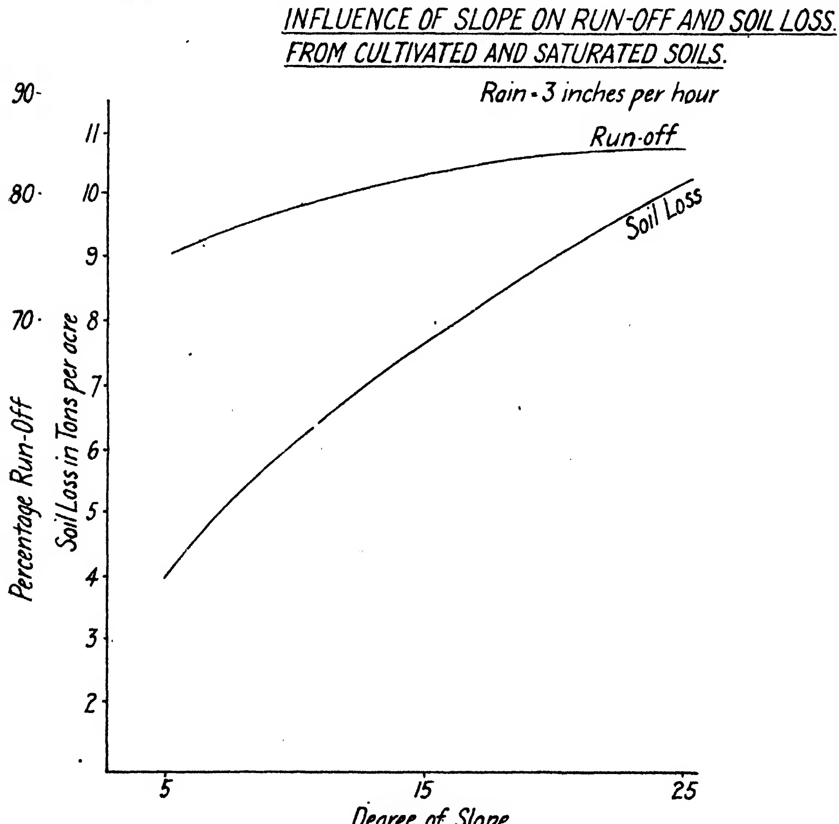


FIG. 4.

topsoil in the field on the steeper slopes exposes a more porous, sandy subsoil in some cases, but in the majority of cases a relatively impervious clay subsoil is exposed.

It is apparent that slopes once stable and protected by native vegetation are no longer sufficiently protected by the induced vegetation (Fig. 5). Soil loss by sheet erosion from regularly cultivated slopes above 12° is such that the greater part of the surface soil is removed in from twenty to forty years.

Under certain conditions permanent pasture does not adequately protect slopes above 15°, with the result that the subsoil is exposed in many cases.

Grazing management, type of pasture, type of soil, and several other factors cause much variation in the ideal management for particular slopes.

SOIL TYPE

Comparative studies were made on the five principal soil types using artificial rain.

TABLE VI

—	Matapiro Cultivated Forty Years.		Waiwhare Sandy Loam.		Gisborne Sandy Loam.		Weber Loam.		Rendzina Loam.	
	Run-off.	Soil Loss.	Run-off.	Soil Loss.	Run-off.	Soil Loss.	Run-off.	Soil Loss.	Run-off.	Soil Loss.
Trials with Cultivated Soils in Boxes (Slope, 15°; Rain, 3 in. per hour)										
First ten minutes ..	38	2·2	4·6	0·55	1·5	0·04	45·8	0·4	2·9	0·07
Second ten minutes ..	67	2·91	29·6	2·43	29·5	0·30	66·4	1·06	45	0·70
Third ten minutes ..	74·4	2·63	41·4	2·14	36·5	0·25	78·5	1·01	51·5	1·13
Fourth ten minutes ..	77·0	2·6	50·5	1·83	41·0	0·19	84·7	0·85	60·0	0·88
Fifth ten minutes ..	80·2	2·54	56·2	1·71	45·1	0·15	88·4	0·86	64·2	0·91
Sixth ten minutes ..	81·5	2·42	60·5	1·52	48·2	0·14	89·3	0·84	67·0	0·78
Field Trials on Grazed Pasture (Slope, 15°; rain, 3 in. per hour)										
First ten minutes ..	43·6	0·24	25·2	..	42	0·05	27·8	0·39	39·2	0·42
Second ten minutes ..	76·6	0·33	54·6	..	48·1	0·16	74·6	1·45	65·6	0·81
Third ten minutes ..	79	0·32	68·4	..	53·1	0·21	81·0	1·56	76·2	0·5
Fourth ten minutes ..	82·5	0·27	74·5	..	57·2	0·17	86·2	1·34	83·1	0·61
Fifth ten minutes ..	84·5	0·25	75·4	..	59·6	0·18	90·5	1·28	84·5	0·41

With the exception of the very porous Gisborne sandy loam, the run-off from the various soil types was fairly uniform. These trials were carried out using boxes of soil in which the soil was apparently more consolidated than under field conditions. The soil derived from volcanic ash (Gisborne and Waiwhare) and the long-cultivated Matapiro soil were most susceptible to loss of soil by sheet erosion.

The lack of structure in these soils is significant; in the former it is inherent, while in the latter it is induced by cultivation.

The above results are well maintained under field conditions on severely grazed and consolidated pastures. Losses of water were greater than on cultivated soils under field conditions.

Severe grazing and tramping appear to overcome differences due to soil type.

FIG. 5.—Severe soil erosion after heavy rain. Ap. 1938. Devil's Elbow.

However, field trials on cultivated soils of each type indicate clearly the individual behaviour of each soil type with respect to run-off and soil loss (Fig. 6). Gisborne and Waiwhare types were most absorbent, while the over-cultivated Matapiro soil and Waiwhare soil were most readily removed by sheet erosion.

The fact that Gisborne sandy loam was least affected by sheet erosion under field conditions and most affected under trials in boxes emphasizes the difficulty in creating comparable artificial conditions in boxes.

Under field conditions Gisborne and Waiwhare loams suffer most from sheet and gully erosion, Weber loam suffers from slippage and flowage, while Matapiro and Rendzina loams suffer moderately from sheet, slip, and gully erosion.

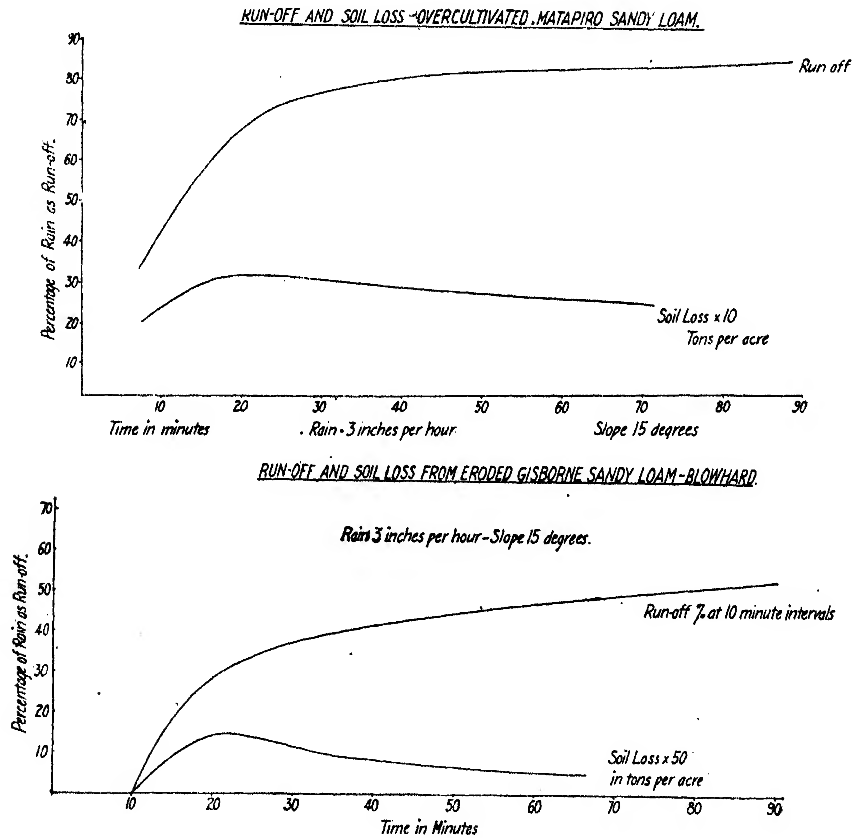


FIG. 6.

In connection with the effect of farming on the erosion of the various soil types, Macdonald Holmes(6, p. 34) states that "the momentum of the erosion cycle in most of the soil types is very much less than the man-made erosion cycle" in the Western Division of New South Wales.

AIR CONTENTS OF SOILS

For the purposes of comparison, the air content of typical samples of soil was obtained by a simple and direct method.

The high air content of unfarmed soils indicates the extent of pore space and suggests that the structural arrangement of the soil is conducive to the rapid movement of water through it. Under consolidated conditions the converse of this appears to be true.

TABLE VII.—AIR CONTENT OF SOILS, BY VOLUME

Condition of Soil and Vegetation.	Depth (Inches).	Number of Samples.	Percentage of Air.
Severely grazed and consolidated pasture	6	4	11·6
Soil cultivated for many years	6	3	19·0
Pasture invaded by fern and manuka	6	3	24·3
Forest soil beneath the litter	6-	4	56·8

LOSS ON IGNITION AND WATER CONTENT OF COMPARABLE SOILS

Considerable change in the content of these has been brought about by land use. The loss on ignition was determined to give an approximate measure of the organic-matter content.

TABLE VIII

Soil and Conditions.	Water Content, as Percentage on a Dry-matter Basis.	Loss on Ignition (per Cent.).
Matapiro soil type—		
Eroded north slope—poor pasture	6·5	7·1
Non-eroded south slope—good pasture	17·1	10·7
Eroded stock paddock almost bare	14·7	4·0
Non-eroded grassland nearby	25·6	7·82
Eroded pasture	16·3	6·55
Non-eroded pasture on roadside	20·1	14·60
Eroded land under cultivation	16·2	4·53
Non-eroded old ungrazed pasture	26·4	10·27
Eroded pasture nearby	12·5	4·96
Crownthorpe sandy loam—		
Rank ungrazed pasture	23·1	9·3
"	22·8	9·0
Poor eroded pasture	9·6	2·7
Eroded slip area	8·4	3·1
Strong bracken fern	24·2	10·4
Strong manuka	23·4	9·3
Medium bush	25·7	11·03
Burnt-over scrub area	12·1	5·6
Waiwhare soil type—		
Rape after pasture	12·4	10·6
Ploughed old pasture	11·3	10·2
Good pasture	15·8	9·3
Rendzina soil type—		
Poor pasture	9·4	7·6
Poor pasture	7·3	6·5
Eroded slip area	6·8	1·3
Rank roadside pasture	18·3	12·6

The above samples were collected when the soils were moderately wet, and serve to illustrate the effect of vegetation and extent of erosion on water and organic-matter content.

Analyses of soils from comparable situations (with respect to slope and soil type) prove that water and organic-matter content decline under severe grazing and cultivation and are lowest on severely eroded areas. The appearance and productivity of soils in the field confirm these results.

SOIL STRUCTURE DETERMINATIONS IN RELATION TO TYPE OF VEGETATION AND USE OF LAND

Two hundred-gram samples of air-dried soil from each situation were shaken with a rotational movement for five seconds and the fractions held on each sieve weighed, while the smallest fraction was retained in a basal tray.

TABLE IX.—STRUCTURE DETERMINATION

Soil Conditions.	Number of Samples.	Diameter of Aggregates.				
		Over 6 mm.	3–6 mm.	1–3 mm.	0·5–1 mm.	Under 0·5 mm.
Matapiro soil type :—						
Forest	3	52·5	23·7	13·0	7·75	1·25
Manuka	3	30·0	23·5	17·75	17·25	6·0
Bracken fern	3	36·7	22·5	17·75	17·25	6·3
Ungrazed grasses ..	4	30·0	29·9	19·5	19·0	4·0
Good grazed pasture ..	3	23·0	22·3	20·2	24·6	9·2
Soil cultivated for forty years	3	13·2	18·2	21·0	29·6	18·3
Silt deposit from recent flood	2	..	4·5	12·5	20·0	62·5
Older alluvium under grass	2	44·0	25·25	16·25	8·75	5·75
Rendzina soil type :—						
Forest	2	42·5	20·0	17·5	12·5	5·0
Ungrazed grasses ..	2	51·0	23·5	12·3	8·1	5·5
Grazed pasture	3	34·3	23·3	15·1	12·3	13·0
Poor pasture	2	20	20	19·5	23·0	17·5

Considerable differences in the proportion of the various aggregates according to the condition of the soil suggest a corresponding variation in the erodibility.

TABLE X.—WATER-STABLE STRUCTURE

Soil Type and Condition.	Number of Samples.	Diameter of Aggregates.				
		Over 6 mm.	3–6 mm.	1–3 mm.	0·5–1 mm.	Under 0·5 mm.
Matapiro						
Forest	2	44·9	18·6	11·6	8·4	16·5
Pasture	2	34·4	27·0	14·3	13·4	9·1
Cultivated one year ..	2	18·2	11·8	11·0	33·5	24·5
Cultivated forty years ..	2	1·8	4·0	5·7	19·9	67·5
Gisborne loam—						
Roadside pasture ..	2	34·2	13·8	9·4	25·2	16·5
Cultivated	2	4·4	8·2	10·5	22·0	53·5
Severely eroded	2	6·5	19·4	18·2	30·1	26·0

The variation in proportion of aggregates of each size is pronounced in various soils. The reduction in size and number of aggregates on farmed soils suggests that structure, measured in terms of water-stable aggregates, declines with land use. The effect of continuous cultivation on the disintegration of water-stable aggregates has been established experimentally, and helps to explain the apparent " melting " or liquifying of such a soil during heavy rain.

FIG. 7.—Well-developed soil structure under forest, Tangoio.

FIG. 8.—Well-developed soil structure under lightly grazed pasture, Tangoio.

Yoder(7) states that "organic colloidal cements may yield water-stable aggregates capable of resisting many alternate wettings and dryings in the field. On the other hand, most of the inorganic colloidal cements hydrate or dehydrate readily with alternate wettings and dryings, with the result that the soil is characterized by an unstable structure." Beaver and Rhoades(8) found "that soils high in organic matter contain 15 per cent. to 30 per cent. more granules than those low in organic matter and that the granules are three times more stable."

The difference between grassland and certain forest soils in respect to water-stable aggregates is not as great as other evidence suggests (Figs. 7 and 8). However, this method does not measure the stability of the aggregates *in situ*, and it appears probable that the handling of the sample is sufficient to disintegrate the less-stable aggregates of forest soils.

WATER-HOLDING CAPACITY

During the progress of the investigations the water-holding capacity of various soils was determined, and these were of interest, particularly in relation to type of cover.

TABLE XI

Habitat and Layer.	Average Percentage of Water held (on a Dry-weight Basis).	Number of Samples.
Gisborne sandy loam—		
Forest rimu surface layer, 2½ in. to 6 in. in depth	151	3
Forest mixed bush floor, 6 in. to 8 in. in depth	100	3
Manuka, 4 in. in depth	104	2
Bracken fern, 4 in. to 8 in. in depth	94·6	3
Grassland, 6 in. in depth	65·3	6
Cultivated, 6 in. in depth	42·8	5

However, a more practical comparison reveals greater uniformity in respect to absorption :—

TABLE XII

Condition of Soil.	Average Water-holding Capacity (per Cent.).	Average Specific Gravity.	Rain absorbed per Inch Depth of Dry Soil (Inches).
Gisborne sandy loam—			
Forest—			
Litter	200	0·5	1·0
Top 6 in.	100	1·3	1·3
Pasture: Top 6 in.	65	1·7	0·99
Cultivated: Top 6 in.	43	1·9	0·81

The water-holding capacity (as measured by the absorption per unit weight of air-dried soil) of those soils rich in organic matter contrasts definitely with those under cultivation. Translated into inches of depth of soil there is greater uniformity in behaviour. Under ideal conditions of infiltration the capacity of a soil to hold water would appear to be limited by its depth and initial water content. Under natural conditions the maximum water-holding capacity of the soil can be utilized, but under farmed conditions this is seldom possible owing to the surface-soil conditions not being conducive to rapid infiltration.

LITTER

The influence of litter in reducing run-off and soil loss is prominent in trials.

TABLE XII

—	Slope (°).	Run-off (per Cent.).	Soil Loss (Tons).
Forest			
Undisturbed—rain, 3 in. per hour	25	..	..
Litter removed	25	1·1	0·08
Grassland—			
Poor danthonia pasture	20	45	0·47
Poor danthonia plants removed	20	72	2·5
Partial cover (stock paddock)—			
25 per cent. to 30 per cent. cover and litter ..	15	60	1·84
Bare ground	15	73	3·12

The protection of the surface soil from direct battering by raindrops, the stabilization of the surface, and the resistance to surface flow appear to be important attributes of litter. The development of a thorough network of surface rootlets was associated with a well-developed layer of litter (Fig. 9), but such a woven layer is not found on partially bare soil.

Under severely grazed pasture conditions the surface layer is coated with a tramped matrix of dead leaves, seed heads, stalks, and dung, which was found to be relatively resistant to the action of raindrops. When this layer is shaved off, loss of soil and water increases considerably. Under forest, fern, flax, and scrub the greater depth of litter is more effective, but the absorptive capacity of the litter is not sufficient to account for the remarkable intake of rain under these conditions. The protective and stabilizing effect of litter appears to be of greater importance than its absorptive capacity.

LITTER AND ROOTS

The previous experiment indicated that the abundance of surface roots has a considerable influence on soil stability and porosity, consequently it was arranged to eliminate, in sequence, the effect of litter, roots, and structure.

TABLE XIV

(Rain, 3 in. per hour; two 20 min. applications)

Treatment.	Slope (°).	Run-off (per Cent.).	Soil Loss.	Soil Loss, Tons per Hour.
(1) Normal forest floor, Crownthorpe sandy loam	25 25	.. 0·40	.. ..	.. ..
(2) Forest floor, litter removed	25 25	0·45 1·1	.. 0·08	.. 0·44
(3) Forest floor, litter removed and dug 8 in. to destroy the influence of roots	25 25	2·2 5·8	0·09 0·15	0·27 0·45
(4) Forest floor dug up 8 in. deep	25	15·3	0·08	0·24
Raked over and consolidated	25	47·5	0·13	7·15

In the previous trials it was apparent that the abundance of rootlets in the lower layers of the litter had an influence on soil stability, porosity, and structure.

The removal of the surface litter resulted in small surface losses of water and soil. The removal of the influence of roots by digging the forest soil resulted in increased loss of water by surface run-off, but there was no appreciable loss of soil. The subsequent cultivation and consolidation by tramping of forest soil created conditions favourable to surface run-off and

FIG. 9.—Dense root array and good structure in forest soil, Tangoio.

soil loss comparable with those sustained under cultivation. The structure developed in association with much litter and a dense array of roots appears to be a potent factor in assisting infiltration. In addition, the extensive and deep roots increase the effective depth of soil and subsoil for the absorption of water and for the disposal of excess water by percolation.

BINDING CAPACITY OF ROOTS

An excellent opportunity of comparing the binding effects of types of roots was afforded in the Esk silt on areas where an incomplete cover of grasses, clover, lupins, and barley was found. The plants were loosened with a spade, a rope tied round the crown of the plant, and it was weighed with the adhering silt. The mass was then placed in water, the silt was removed, and the roots were weighed. By this means the soil-binding capacity of the roots could be roughly measured.

TABLE XV

Plant.	Weight of Earth and Plant (lb.).	Weight of Plant (lb.).	Weight of Roots (lb.).	Ratio $\frac{\text{Earth}}{\text{Roots}}$
Barley	7·2	0·26	0·06	114
Prairie grass	35	1·1	0·25	130
Rye-grass	10·3	0·18	0·07	143
Tall fescue	40	2·1	0·34	110
Plantain	18	1·0	0·14	120
Lupin	1·3	0·91	0·04	8
"	1·1	0·62	0·05	8
Red clover	11	0·24	0·11	96
White clover	11	0·30	0·14	75

The long and very numerous fibrous roots of grasses permeate the soil so thoroughly that the entire mass of silt beneath the plant can be lifted bodily with little difficulty. The ratio of the soil lifted to the weight of the roots was very high with grasses in comparison with other plants tested.

The binding effect of the roots is well exemplified in this trial, but the total soil contacted by the roots is not accounted for owing to the breaking of fragile rootlets. The extent of the rooting system was indicated by Pavlychenko(15), who found that a single wild oat plant eighty days old had a root system fifty-four miles in length.

In order to obtain an indication of the relative quality of roots per unit area, 2¾ in. cores were obtained with a soil sampler to a depth of 8 in.

The samples were soaked thoroughly and washed on a fine sieve, and the roots were removed from the mass with forceps and weighed.

TABLE XVI

Type of Vegetation.	Weight of Roots (Grams per Core).
Rimu bush	10·8
Manuka scrub	1·85
Flax	2·15
Good pasture	3·25
"	4·1
Ungrazed pasture	5·1
Poor pasture	0·22

Roots greater than 0·25 in. diameter are excluded.

The binding-capacity has a greater significance when the weight of roots in the top 8 in. of soils is estimated quantitatively. There are apparently sufficient roots to stabilize the soil beneath vigorous vegetation. By contrast, the loss of this binding effect by roots must seriously interfere with the stability of the soil.

The binding effect of grass roots can be frequently observed on eroded areas, where numerous islands of danthonia (1 ft. to 3 ft. in diameter and 2 ft. in depth) are the surviving remnants of vegetation. Larger islands of native flax (Phormium) are also very common (Fig. 10).

FIG. 10.—Roots of flax plants resist soil erosion until undermined, Blowhard.

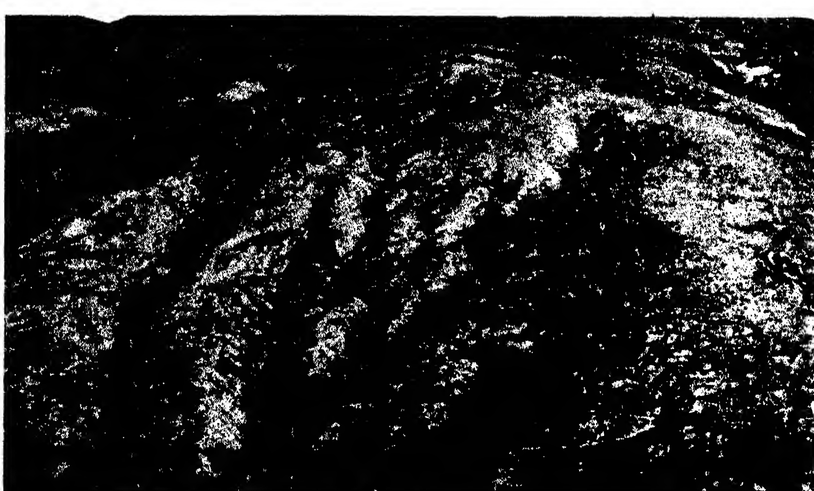


FIG. 11.—Frequent burning has accelerated the removal of topsoil by sheet erosion on this hillside, Kuripapanga.

BURNING

Considerable increase in run-off and soil loss occurred as a result of burning off the vegetative cover.

TABLE XVII.—COMPARATIVE TRIALS ON THE INFLUENCE OF BURNING ON RUN-OFF AND SOIL LOSS

(Rain, 3 in. per hour; slope, 16°)

Soil and Vegetation.	Unburned.		Burned.	
	Run-off.	Soil Loss.	Run-off.	Soil Loss.
Matapiro type: Lightly grazed danthonia ..	32·2	0·01	52·5	0·83
Waiwhare soil type: Manuka and tutu ..	..	..	56·0	1·45
Gisborne loam: Danthonia pasture	21·4	0·02	33·2	0·48
Weber loam: Danthonia pasture	34	Trace	54·4	1·01
Rendzina soil: Rank pasture	2·5	..	22·4	0·86
Matapiro loam: Manuka scrub	..	..	44·8	1·24

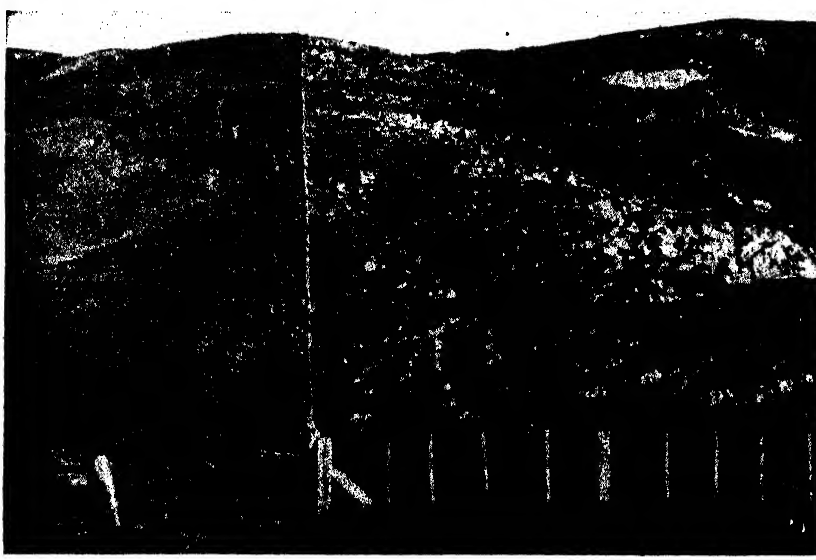


FIG. 12.—Severe erosion on a holding paddock, contrasted with conditions in the next field, Tangoio.

Many detached soil particles were found on the burnt surfaces, which were hitherto held in position by the surface litter and tillers of grass prior to the burn. These particles disintegrated rapidly with rain and together with the ash were washed into and apparently clogged the pores of the soil. Lowdermilk(10) found that the application of a 2 per cent. clay suspension rapidly clogged the pores of an unprotected soil, reducing the percolation rate by 90 per cent. He also found that the destruction of organic matter with a blow-lamp increased run-off three to sixteen times and soil loss twelve thousand times. From data in a later section it is shown that stems play an important part in acting as conduits for water into the soil from the collecting area of the leaves above. This mechanism is modified by burning

and the protective effect of surface litter is lost, enabling the rain to beat directly on the surface soil and cause movement of the unorganized soil particles.

It is apparent that a hot, clean burn destroys vegetation and surface litter and predisposes the soil to considerable losses (Fig. 11). The widespread practice of burning native grassland, scrub, and fern has a much greater significance as a contributory cause of soil erosion, when the actual losses are measured and the cessation in supply of organic matter to the soil is considered.

TRAMPING BY LIVE-STOCK

Critical information on the effect of tramping by live-stock was obtained by comparing heavily stocked areas with controls nearby.

TABLE XVIII.—EFFECT OF CONSOLIDATION BY TRAMPING

(Slope, 15° ; rain, 3·1 in. per hour ; Crownthorpe sandy loam)

Habitat.	Normal.		Consolidated by Tramping.	
	Run-off (per Cent.).	Soil Loss, in Tons per Acre.	Run-off (per Cent.).	Soil Loss, in Tons per Acre.
Forest	..	..	21	0·002
"	..	..	58	1·3
"	0·9	..	30·4	0·07
"	..	..	32	0·85
Manuka scrub	..	..	24·6	0·13
Bracken fern	..	..	27·5	0·05
Ungrazed pasture	0·8	..	53·5	0·12
Grazed pasture	42·6	0·003	62·8	0·63
Cultivated soils	3·6	0·005	31·1	2·2
"	15·4	3·0	57·0	6·8

In all cases the increase in loss of surface soil and water as a result of tramping is of such magnitude that this factor must be considered one of the most potent in accelerating soil and water losses.

The results indicate the serious effects that live-stock can have on native associations of plants in New Zealand and the critical value of management of pastures in relation to soil and water conservation. Not only is vegetation cut and mutilated by the sharp front wall of the hoof, but consolidation of the surface layers interferes vitally with several important characteristics of the soil discussed above.

In the United States of America, Bowman(11) states, "the effect of tramping is well known throughout the West, vegetation is not only destroyed, but the ground is hardened, humus is oxidized, and litter is broken up and washed away."

The effect of excessive tramping is well illustrated on various holding paddocks in the province (Fig. 12).

CULTIVATION

Comparative trials were made on soils that had long been under cultivation with those recently cultivated from pasture. Successive twenty-

minute applications of rain at 3 in. per hour intensity were applied to slopes of 15° in each case on wet Matapiro soils.

TABLE XIX

Condition of Soil.	Run-off, as Percentage of Rain.	Soil Loss, in Tons per Acre.
Fallowed land, *firm surface*, forty years under cultivation, Matapiro sandy loam	80	0·9
Ditto	83	1·02
"	85	1·32
Same land, recently *hoed 2 in. deep*	35·7	0·55
"	36	1·8
"	64	3·85
Same land, *lightly dug over*	15·4	3·0
"	49	6·6
Same land, *recently cultivated—fine and firm*	57	6·8
"	64	8·0
Adjacent plot *recently ploughed and disked from pasture* ..	0·7	..
" ..	3·6	0·005
" ..	7·1	0·012
Same plot further *harrowed, rolled, and consolidated* ..	31·1	0·12
" ..	36	0·23

FIG. 13.—Sheet erosion has resulted in the removal of 18 in. to 20 in. of soil that has exposed the roots of these vines, Havelock North.

The greatest losses of soil and water measured were from cultivated land. The losses varied according to the soil type, condition of the surface (hard and firm, lightly dug, or merely hoed 2 in. in depth), and the length of time under cultivation. The effect of light cultivation (hoeing 2 in. in depth on fallowed soil) considerably reduced run-off during the first hour of rain, but the loosening of the soil caused a marked increase in soil loss after twenty minutes. Such a mulch results in extravagant losses of soil in rains of high intensity or long duration (Fig. 13).

Deeper cultivation (digging 7 in. in depth) reduced run-off considerably, but caused greater loss of soil after an interval of thirty minutes.

Comparisons between overcultivated soil and soil recently cultivated from old pasture revealed that losses were of a much lower order from the latter. Further cultivation and consolidation of the latter increased soil and water losses, but the soil aggregates retained their individuality and remained rigid. Evidence that soil and water losses vary according to soil type was indicated above.

Overseas evidence of the behaviour of soils under cultivation is confirmed with respect to the soils of Hawke's Bay. The length of time that they can be safely kept under cultivation varies according to slope, soil type, climate, and crop rotation.

INFILTRATION STUDIES

The rates of infiltration were compiled from numerous experiments with natural and artificial rain in the field, from trials with soils in boxes, and from brass tubes 1 in. in diameter that were pressed into the soil.

TABLE XX

(a) *Effect of Vegetation on Rate of Infiltration*

Forest	Greater than 5·6 in. per hour.
Manuka	" 3 "
Phormium	" 3 "
Bracken fern	" 3 "
Native tussock	" 4 "
Ungrazed grass	" 3 "
Grazed grass	0·73 in. to 1·3 "
Poor pasture	0·4 in. to 0·99 "
Eroded pasture	0·25 in. to 1·4 "
Completely eroded surfaces	0·25 in. to 0·68 "
Burnt pasture	0·45 in. to 1·2 "
Fallow and cultivated	0·22 in. to 1·83 "

(b) ***Effect of Soil Types on Infiltration in Saturated Soils (in Boxes)***

—	Infiltration Rates, in Inches per Hour.		
	5° Slope.	15° Slope.	25° Slope.
Matapiro: Cultivated for forty years	0·55	0·50	0·40
Matapiro: Recently cultivated	0·65	0·60	0·50
Waiwhare: Recently cultivated	0·65	0·60	0·60
Gisborne: Recently cultivated	1·90	1·35	1·3
Weber: Recently cultivated	1·0	0·55	0·45
Rendzina: Recently cultivated	0·90	0·60	0·55

(c) *Effect of Duration of Rain (on Dry Soils* in situ) *on Infiltration*
(Matapiro soil type (Fig. 14); 10 minute intervals; intensity, 3 in. per hour)

	Grazed Pasture Infiltration Rate (Inches).		Cultivated and Fallow Infiltration Rate (Inches).	
	Per Ten Minutes.	Per Hour.	Per Ten Minutes.	Per Hour.
First	0·32	1·92	0·33	1·98
Second	0·22	1·32	0·23	1·38
Third	0·15	0·90	0·19	1·4
Fourth	0·13	0·78	0·16	0·96
Fifth	0·125	0·75	0·13	0·78
Sixth	0·125	0·73	0·12	0·72

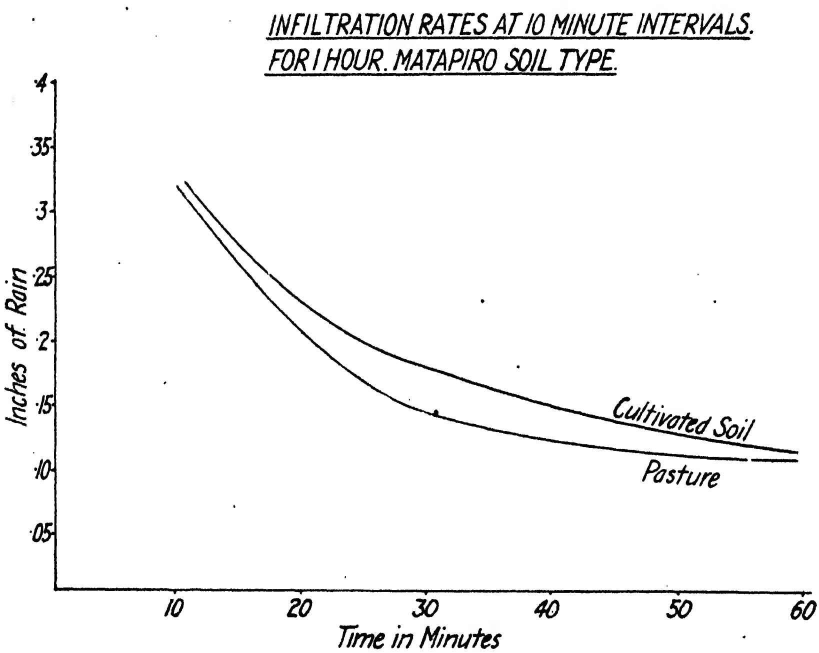


FIG. 14.

For purposes of comparison, samples of soil were obtained in 1 in. diameter cores in sharpened brass tubes 12 in. long. These tubes were forced into each soil until a core 6 in. in depth was obtained. To each tube 100 ml. of water was added and the percolate was measured and the rate of infiltration recorded as follows:—

TABLE XXI

Type of Cover.	Infiltration Rate, in Inches per Hour.
Bush	23·7
Manuka scrub	20·8
Bracken fern	10·3
Ungrazed pasture	6·7
Pasture closely grazed	1·5
Eroded clay slip	0·012

Previously determined infiltration rates agree with the latter two results, but no comparisons can be made with the former results, since the rain applied

was not of sufficient intensity and duration to satisfy the maximum rate of infiltration.

From the results it appears that the influence of type of vegetation and the associated soil conditions is of paramount importance in respect to the rate of infiltration. The sharp decline in the rate on farmed land is very significant.

The variation in rate due to differences in soil type is clearly in evidence in the second series of figures. Gisborne sandy loam, which is of pumiceous origin, has approximately four times the infiltration capacity of over-cultivated Matapiro soil. The rate at which infiltration declined during the first hour of rain was fairly constant on both fallow and grazed pasture land. There was a tendency towards a higher rate of infiltration with the lower intensity of rain when used on fallow land. This was possibly due to the reduced turbidity of the run-off.

When the infiltration rate was measured by brass tubes, much higher rates were obtained for unfarmed soils, but on farmed soils results agreed with those obtained by the other method.

The rate of infiltration appears to be a useful criterion for evaluating soil reaction in the field under the large range of conditions of soil and vegetation found in Hawke's Bay. As a relatively small area of the province is cultivated, the influence of pasture and native plant cover on infiltration is important. It has already been shown that run-off varies according to the severity of grazing and tramping of pasture land, hence pasture management becomes the most important factor controlling the total infiltration of the area.

Infiltration rate exhibits a high degree of correlation with porosity (measured by displacement of air), structure (as measured by content of water-stable aggregates above 0·5 mm.), and organic-matter content (indicated by loss on ignition).

These characters are largely conditioned by litter and root array, which are dependent upon type of vegetation. The vegetation, in turn, can be regarded as a product of land use. Consequently, it is not surprising to find a high degree of correlation between land use and rate of infiltration.

As soil and water losses can be regarded as a function of the lack of effective vegetation, it is expected that soil erosion is correlated with the deterioration of vegetation. Under field conditions the inception of soil erosion is closely associated with deterioration of plant cover.

When dealing with a habitat, two groups of factors are operative—those of the soil and those of the plant. This soil-plant complex has clearly been evolved by the interaction of each, and infiltration can be regarded as the resultant of this interaction. Under natural conditions the plant appears to dominate the reaction of the complex, but under farmed conditions a more evenly balanced effect is exerted by soil and plant factors. On over-grazed, overcultivated, and eroded land the roots, organic matter, and structure have been gradually eliminated, consequently the infiltration rate falls to the level of the inherent capacity of the inorganic constituents of the soil.

This important factor is, according to authorities, best indicated by dispersion ratio and ratio of colloid to moisture equivalent (Ayres(12, pp. 25–29) and Bennett(13)).

In Hawke's Bay, where a large proportion of the area is covered by a permanent vegetation, this basal rate of infiltration does not appear to be as important as the influence exerted by plants on the rate of infiltration.

INTERCEPTION AND CONTROL OF RAIN BY PLANTS

The above investigations indicate that the factors associated with a mature soil-plant complex expedite infiltration and reduce surface soil and water losses almost to zero. Elimination of the plants concerned by grazing, burning, or cultivation causes greater run-off and soil loss, suggesting that the plant plays a direct role in assisting infiltration.

During the previous investigations it was observed that the distribution of rainfall beneath vegetation was erratic and that the soil near the roots of isolated plants was wetter than the surrounding soil after application of rain.

The interception by foliage and branches of various plants was investigated under natural and experimental conditions. In the first instance rain-gauges were placed beneath individual plants and the series of readings was compared with a control gauge. It was found that the drip and rain penetrating the foliage of dense shrubs and trees was varied in its distribution, and on the average of twenty-two trials was from 18 per cent. to 30 per cent. of the quantity recorded by the control gauge.

Further trials were carried out in heavy mixed podocarp-dicotylous forest at Ohurakura to determine the relative effectiveness of different types of vegetation in intercepting rain.

During a period of twenty weeks, 20·15 in. of rain was recorded in the clearing, but only 12·70 in. of rain, or 44·4 per cent. of the above, was recorded on the forest floor. On ten occasions the rainfall was less than 0·55 in. in the open, but only in two of these cases was there any rain recorded by the gauges in the bush. On the remaining ten occasions an average of 45·1 per cent. of the normal rainfall was recorded on the forest floor. Light rains are apparently almost completely intercepted by the canopy of vegetation, while rains of high intensity are partially intercepted (average, 54·9 per cent.). The reduction in the percentage of rain intercepted appears to be due to the reduced time available for evaporation and to the greater momentum and splash from larger drops of rain. The dispersed rain drops and drips reaching the ground surface were readily absorbed by the moss and litter covering the forest floor or penetrated rapidly to lower horizons.

Interception by grasses was measured by placing gauges between tufts of rank grass. Over a period of three months the average of ten gauges revealed that 90 per cent. of the rainfall was intercepted. The figure applies to the areas not occupied by the crowns of plants and must be corrected according to the density of the sward. On the major proportion of a grassland area the rain falls on, or is conducted into, the dense mass of tillers forming the crown of the plant.

These trials indicate how two types of vegetation interfere with the rainfall and bring under their control a considerable proportion of it. Musgrave and Norton(14) measured the percentage of rain intercepted as follows: Corn, 21·9; alfalfa, 21·2; and clover, 18·6.

The quantity of water retained on the leaves was checked by immersing the leaves of several plants in water and weighing again when the drip ceased. The weight of water adhering to the average green leaf was 35·7 per cent. of its weight, to dead leaves and leaf mould 144·5 per cent., and to moss 413 per cent.

A proportion of rain was thus controlled by the leaves and evaporation was facilitated during and after the rain. The proportion of rain evaporated from leaves depends upon the intensity of the rain, temperature, humidity, and wind.

In order to account more fully for that proportion of the rain brought under the influence of the plant, artificial rain was applied to areas of 2 square feet of vegetation arranged to simulate the natural density of leaf and twig spacing. The quantity of water held by the leaves, the quantity of drip,

and the quantity draining down the stems was measured after the application of 0·5 in. of rain in ten minutes to this area of vegetation. Approximately 10·4 per cent. of the rain was not accounted for and was lost as splash from the leaves within the area. The average results of ten trials indicated that 12·6 per cent. adhered to the leaves, 36 per cent. fell on the ground surface, and 36·8 per cent. drained down the branches into collecting bottles.

The experimental error introduced by splash from the leaves and insufficient rain-gauges was reasonably low under the circumstances. Manuka was the most effective plant tested in this group, the small leaves of which make acute angles with the stems and twigs that are closely spaced to form a dense canopy.

The results of these trials were further checked on a chestnut-tree 16 ft. in height with a spread of branches of 83·2 square feet. The quantity of rain falling on the tree was calculated, while the drip and water flowing down the trunk were measured (the latter was measured after being deflected into a large vessel).

TABLE XXII.—INTERCEPTION OF WATER FLOWING DOWN TRUNK OF CHESTNUT-TREE 16 FT. HIGH

Date.	Rainfall (Inches).	Control Gauge (ml.).	Average of Eight Gauges under Tree (ml.).	Percentage of Rain falling under Tree.	Rain-water draining down Trunk (lb.).	Percentage of Rain.	Percentage of Rain not accounted for.
Dec. 12 ..	0·40	65	11·1	17·07	79	47·2	35·73
13 ..	0·53	82	26·6	32·4	112	49·9	17·7
Jan. 12 ..	0·53	82	24·1	29·5	110	50·0	20·5
13 ..	0·17	30	7·3	24·3	38	53·3	22·4
21 ..	0·03	4	0·9	22·5	6·5	51·9	25·6
25 ..	0·04	7	1·1	15·8	7·1	42·4	40·8
27 ..	0·12	20	5·1	25·5	25·2	49·6	24·9
28 ..	0·04	7	1·1	15·8	6·5	38·1	46·1
Feb. 3 ..	0·04	7	1·5	21·4	8·5	50·4	78·8
4 ..	0·12	22	6·6	30·0	25·0	50·8	19·2
6 ..	0·06	10	1·3	13·0	10·3	40·3	46·7
24 ..	0·03	4	1·0	25·0	5·4	40·9	34·1
24 ..	0·07	13	4·5	34·6	16·2	54·8	10·8
24 ..	0·24	41	14·3	34·8	38·4	45·2	20·0
24 ..	0·29	48	12·6	26·2	48·7	37·4	36·4
24 ..	0·20	35	13·1	37·4	30·5	37·3	25·3
Mar. 1 ..	0·07	12	2·65	21·2	17·2	57·7	21·1
1 ..	0·05	8	3·5	17·2	9·4	45·6	37·1
1 ..	0·09	15	3·25	21·6	19·6	57·6	20·8
1 ..	0·09	16	3·25	20·4	22·4	58·4	21·2
12 ..	0·05	6	2	33·3	8·2	40·6	26·1
14 ..	0·30	50	16·0	32·0	8·2	48·2	19·8
Apr. 2 ..	0·1	20	5·1	25·7	22·1	52·1	22·2
13 ..	0·16	30	8·3	27·6	36·6	54·2	18·2
15 ..	0·30	48	17·0	35·4	67·7	53·7	10·9
18 ..	0·55	85	35·1	37·9	116·2	50·8	11·3
20 ..	0·11	21	5·1	24·3	16·2	35·4	40·3
21 ..	0·74	120	43·5	36·2	153	30·7	13·1
Average percentages	..	..	..	26·3	..	48·2	25·5

Over a period of five months (Table XXII) the averages for the destination of the rainfall were as follows: 73·7 per cent. was intercepted, and 26·3 per cent. reached the ground surface beneath the tree as dispersed rain and drip; 48·2 per cent. of the total rain flowed down the trunk of the tree, and the remaining 25·5 per cent. of the intercepted rain adhered to the foliage or was evaporated. It was noted that a larger percentage of the rainfall reached the ground surface beneath the tree during the rains of higher intensity.

The high proportion of rain-water flowing down the trunk of the tree was further investigated by measuring the rate at which water flowed along the roots of the tree. The rate of flow (measured by absorption of cotton-wool tied round typical roots) was sufficient to account for the disposal of the water flowing into the soil at the base of the tree.

Further trials were carried out on forest trees in order to observe the comparable effects of rain of high intensity. Water was poured down the trunks of trees at a rate of flow calculated to be equivalent to the flow down the trunk of such a tree during a 4 in.-per-hour rain. As there was no surface run-off, it was concluded that the root system was capable of conducting into the soil the maximum flow down the trunk that was likely to occur. During and after very heavy rains there was no evidence of surface run-off from the bases of trees, except where the soil was tramped and consolidated by stock.

Further confirmatory evidence of the activity of roots was obtained from the examination of wetted profiles after a heavy rain on previously dry soil. Thirty-two pairs of observations were made comparing the penetration of rain beneath plants and on bare ground, the average results of which were 8·3 in. and 2·0 in. respectively. The rain penetrated most deeply by way of the root system, producing typical V-shaped wet cores below individual plants. By comparison, penetration was very limited on bare, tramped soil.

Examination during heavy rain reveals that forest trees vary considerably in their capacity to intercept and conduct rain into the ground. The effective depth of the canopy and its resistance to penetration of rain largely depends on the life form of the tree. Infiltration near the tree and flow along the roots is assisted by the litter and loosely arranged soil particles that are held in place by the tangled mass of surface rootlets. Associated with most forests is a liberal growth of mosses, lichens, and decaying wood, which are very absorbent. The capacity to accommodate high rainfall appears to be greater in forests owing to the very deep penetration of the roots and well-developed structure that brings into operation the maximum water-holding capacity of the soil.

Although the life form of native grassland contrasts sharply with that of forest, certain characters associated with it compensate for the reduced canopy. The basal portion of the tussock grasses (6in. to 24 in. diameter) is large in proportion to the total spread of the foliage, consequently a large quantity of the total rainfall is either conducted into or falls directly on to this basal portion. The butts of the tussocks occupy from 10 per cent. to 50 per cent. of the total area of the ground surface and consist of an organized litter made up of dead leaves held in place by numerous living tillers. Such a butt is from 13 in. to 16 in. above ground and extends below ground-level to a depth of from 3 in. to 12 in. Smaller turf-forming species occupy the ground between the tussocks, to provide a very thorough cover. The abundance of fibrous roots hold the surface layers of the soil much more rigidly in place than do the larger surface rootlets of forest trees.

Evidence has been produced to prove that a varying proportion of rain is intercepted by the foliage of plants and that it is conducted down the stems and into the soil by the roots, along which it flows freely.

The proportion of rain brought under the direct control of the plant varies from 50 per cent. to 90 per cent. in associations of native plants.

Various combinations of roots, foliage, and litter found in native associations of plants appear to be so adjusted that protection is afforded from the intensities of rain experienced. On farmed land such protection is impaired by the consolidation of the soil and reduction in quantity of foliage.

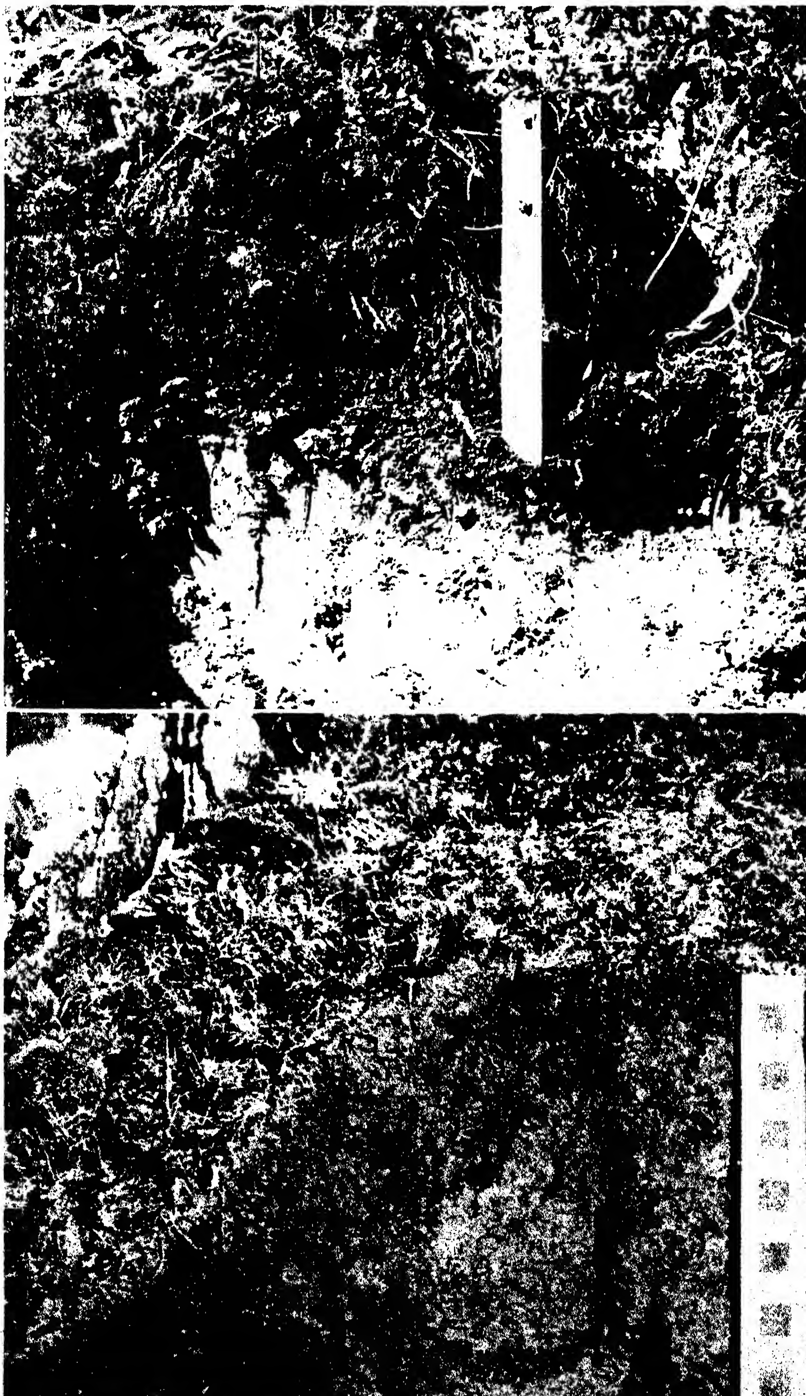


FIG. 15.—Transition from forest conditions (above) to farm land (below) by burning, grassing, and grazing, Tangoio.

In the United States of America erosion-control practices (afforestation and restricted grazing), as well as measurements of run-off and soil loss from various types of vegetation, confirm the value of the complex conditions created by vigorous vegetation, but no mention is made of the direct activity of the plant.

From the figures quoted and observations made on the range and extent of native plant associations it can be deduced that the survival value of adaptations favouring conservation of water is high in many habitats.

The dynamic activity of plants in conducting water into the soil completely reorients conceptions of the conservation value of plant cover.

CONCLUSION

The marked contrast between surface losses of soil and water from farmed soils and those under natural conditions is very significant. Comparative studies of the various factors controlling run-off and soil loss indicate their relative importance. The dominating influence of mature native vegetation with its extensive roots, deep litter, and well-developed soil structure is significant in controlling surface losses of soil and water.

Investigations show that land use or management factors—burning, grazing, and cultivation—used by man, bring about changed relationships, the extent of which largely conditions losses of soil and water. Progressive consolidation accompanied by destruction of surface vegetation, litter, roots, and organic matter leads to loss of structure and water-holding capacity, with the result that the infiltration rate of the soil declines. The rate of decline is closely related to slope and soil type ; while surface losses of soil and water are governed by these factors together with the intensity and duration of the rain. The evidence collected indicates that, save for negligible geologic erosion, soils under natural conditions are not erodible ; but the compact, modern counterpart of these soils is erodible to a degree that is contingent upon the severity of the management practised (Fig. 15).

REFERENCES

(1) JACKS, G. V., and WHYTE, R. O.: Erosion and Soil Conservation. *Tech. Comm. 36*, Imp. Bur. Soil. Sci., 1938, p. 144–5.

(2) RULE, G. K.: Soil Defence in the North-east. *Farmers Bull, 1810*, U.S.D.A., 1938.

(3) NEALE, J. H.: The Effect of the Degree of Slope and Rainfall Characteristics on Run-off and Soil Erosion. *Assn. Am. Soil Sci. Proc., ii*, 1937.

(4) AYRES, Q. C.: "Soil Erosion and its Control," p. 22. McGraw Hill Book Co., New York, 1936.

(5) BENNETT, H. H.: "Soil Conservation and Flood Control." Address before Connecticut Engrs. Congr., U.S.D.A., 1936, p. 28.

(6) MCDONALD-HOLMES, J.: "The Erosion Pastoral Problem of the Western Division of N.S.W.," p. 34. Univ. of Sydney, Australia, 1938.

(7) YODER: The Significance of Soil Structure in Relation to the Tilth Problem. *Assn. Am. Soil Sci. Proc.*, 1939, 22.

(8) BEAVER, L. D., and RHOADES, H. F.: Aggregate Analysis as an Aid in the Study of Soil Structure Relationships. *J. Am. Soc. Agron.*, 1932, 920–30.

(9) BENNETT, H. H.: "Soil Conservation," p. 209. McGraw Hill Book Co., 1939.

(10) LOWDERMILK, W. C.: Influence of Forest Litter on Run-off, Percolation, and Erosion. *J. of Forestry*, 1930.

(11) BOWMAN, J.: "Influence of Land-Water Relationships." Upstream Engrs. Conference, U.S.A., 1936.

(12) AYRES, Q. C.: "Soil Erosion and its Control," p. 25–29.

(13) BENNETT, H. H.: "Soil Conservation," p. 96.

(14) MUSGROVE, G. W., and NORTON, R. A.: Soil and Water Conservation Investigations at the Soil Conservation Experimental Station, Missouri Valley, Loess Region. *Clarinda, Iowa, Bull. 558*, U.S.D.A., 1937, p. 54.

(15) PAVLYCHENKO, quoted in "Soil Conservation," by H. H. BENNETT, McGraw Hill Book Co., 1939.

EXPERIMENTAL POISONING OF SHEEP BY NGAIO (*MYOPORUM LAETUM*)

By I. J. CUNNINGHAM and C. S. M. HOPKIRK, Animal Research Station, Department of Agriculture, Wallaceville

[*Received for publication, 10th January, 1945*]

Summary

(1) New Zealand ngaio (*Myoporum laetum*) was found to be poisonous to sheep. Doses of 7½ g. dried leaves per kilogram body-weight killed sheep in approximately eighteen hours. Lower doses caused depression, loss of appetite, icterus, and photosensitivity.

(2) The primary lesions were congestion of the liver and of the alimentary tract. Icterus and photosensitivity appeared to be secondary, and due to the accumulation of bilirubin and phylloerythrin in the circulation resulting from failure of bile excretion, which, in turn, was caused by congestion of the liver.

(3) Rats were susceptible to ngaio poisoning, but relatively much higher doses were required than for sheep.

(4) The essential oil of ngaio had toxic properties similar to those of ngaio leaves.

THE ngaio (*Myoporum laetum*) is a small tree, 8 ft. to 25 ft. in height, native to New Zealand, which normally grows in coastal regions but may occasionally be found some distance inland.

It is known that ngaio is poisonous to stock, but this property is often forgotten because in normal circumstances the edible portions of the trees are not accessible. Animals may, indeed, run in fields containing ngaio trees for long periods without mishap. Then perhaps some misadventure, such as a violent storm, may lead to branches or whole trees being blown down, the leaves are eaten, and stock are poisoned. The succulent leaves and twigs appear to be very palatable, particularly if they become accessible when the feed supply is short; large quantities are quickly eaten and mortality is usually high. A typical case of ngaio poisoning, which occurred in the Hawke's Bay district in 1942, may be quoted as an example. Forty-four Aberdeen Angus two-year-old heifers were being held in a field in which the feed had become scarce because of dry weather. A storm blew down a ngaio tree and the leaves were quickly eaten by the heifers; three days later twenty-three of the forty-four heifers were found dead.

Aston(1, 2) has recorded some similar cases in cattle and one case in a horse, and Hankin(3) has observed that pigs also are susceptible to poisoning by ngaio.

Cases of ngaio poisoning in sheep under practical farming conditions have not been described, and it was one object of the writers to obtain detailed information in respect to this species. Moreover, the rapid course of ngaio poisoning in natural cases in all species has given little opportunity to study the symptoms and pathology of the condition. It is hoped that the observations recorded on experimental rats and sheep may be of value in this connection.

Most of the work has been carried out on the New Zealand ngaio, but one experiment was made on the poisonous properties of Tasmanian ngaio (*M. serratum*), a closely related introduced species used as a decorative garden shrub.

EXPERIMENTAL

All of the plant material employed was collected near Wellington Harbour. Two collections of *M. laetum* were made, one of leaves, berries, and wood in March, and another of leaves in June. Leaves of *M. serratum* were collected in March. The term "leaves" has been used throughout this paper to indicate leaves plus approximately 4 in. of green terminal branchlets.

Samples were dried at 35° C. and finely ground—the branches being more conveniently dealt with if first reduced to sawdust.

For administration to sheep, the dried, powdered material was suspended in water and dosed through a stomach tube. In rat-feeding experiments the dry powder was incorporated in known proportion by weight into the mixture of cereals, protein concentrates, and minerals which constitutes the stock ration of the rat colony.

Dry-matter figures for the different materials are given in Table I.

TABLE I.—DRY-MATTER CONTENT OF MYOPORUM SAMPLES

Sample.	Dry Matter, per Cent.
M. laetum—	
Leaves	25·4
Berries	49·5
Branches up to 1 in. diameter (wood)	60·0 (approx.)
M. serratum—	
Leaves	24·2

SYMPTOMS IN SHEEP

M. laetum Dried Leaves

A *single dose of 7½ g. dried leaves* per kilogram body-weight was lethal. Death occurred within eighteen hours of dosing and was preceded by dullness and anorexia. On autopsy a considerable accumulation of yellow peritoneal fluid was found, the liver was congested with blood, and the urine deep yellow. The abomasum and small intestines were congested with blood and spotted with pin-point hæmorrhages.

Single doses of 4 g. to 6½ g. dried leaves per kilogram body-weight were not lethal. Depression and loss of appetite occurred, commencing one to two days after dosing and persisting for as long as a fortnight.

A positive van den Bergh reaction was usually obtained in blood-plasma samples drawn the day after dosing, and icterus could be detected in the living animal on the second day after dosing. The van den Bergh reaction became maximal on the second day and then fell steadily, becoming negative within five or six days. In a typical case, which may be quoted as an example, the bilirubin contents of plasma samples taken one, two, three, four, five, and six days after dosing were 0·6, 2·8, 2·2, 2·0, trace, and nil mg. bilirubin per 100 ml. plasma.

Acute photosensitization occurred in treated sheep which were exposed to sunlight. Symptoms usually appeared on the second day after dosing and persisted in an active form for two to three days. Subsequently the œdematous swellings of ears and face subsided and lesions passed through

the normal course to the ultimate formation of dry scabs over the ears and other exposed portions of the skin.

In photosensitive animals abnormal amounts of phylloerythrin and coproporphyrin were present in the blood and urine.

Autopsies made within a few days of dosing revealed marked generalized icterus and a bright-yellow liver. In most cases the mucosæ of the small intestines and the cæcum were inflamed and spotted with small hæmorrhages. The contents of the rectum were hard and dry.

In autopsies made three weeks or more after dosing only slight icterus was noted, the liver was normal in colour, and the intestines were normal.

Single doses of 2·5 g. dried material per kilogram body-weight produced only a slight reduction in appetite, while still smaller doses caused no noticeable effect. No microscopic changes were observed in autopsies made on these cases.

Repeated small doses were not toxic. Ten doses each of 1·5 g. per kilogram given within twenty-four days produced no apparent harmful effect. Four doses of 2·5 g. per kilogram body-weight administered within nine days caused some depression and loss of appetite.

Some cumulative effect appeared to be exerted when individual doses were large enough. Thus, in the second case quoted in the previous paragraph a subsequent dose of 5·5 g. leaves per kilogram body-weight killed the sheep, whereas in other experiments it had been found that a single dose of 5·5 g. per kilogram body-weight was not lethal for sheep which had had no other doses of ngaio.

Fresh Ngaio Leaves

In one experiment fresh ngaio leaves were passed through the juice-extractor. In two doses on two successive days 580 g. of juice were administered to a sheep which weighed 28·8 kg. The juice produced depression, loss of appetite, and icterus—a similar picture to that caused by dried leaves. The histological changes in the liver were the same as those to be described for dried ngaio leaves.

The residue after the extraction of the juice was also toxic, but less so than leaves of the same sample from which the juice had not been removed.

M. laetum Berries and Wood

Doses of dried berries and wood, comparable to those employed for leaves, proved non-toxic. Comparison was made by dosing leaves, berries, and powdered wood to three sheep at the same time and observing them under the same conditions. Table II shows the doses administered and the effect on body-weight.

TABLE II.—SHEEP DOSED WITH DRIED LEAVES, BERRIES, AND WOOD FROM M. LAETUM

Sheep No.	Material dosed.	Dose (Grams/Kilogram Body-weight) and Date.			Body-weight, in Kilograms.		
		30th March, 1942.	8th April, 1942.	13th April, 1942.	30th March, 1942.	13th April, 1942.	8th May, 1942.
A9 ..	Leaves ..	5·5	6·5	..	21·6	18·2	23·0
A40 ..	Berries ..	5·5	10·0	15·0	21·8	20·4	22·0
A19 ..	Wood ..	5·5	10·0	15·0	19·3	18·3	20·2

Sheep A9, which was dosed with leaves, developed a mild degree of icterus, and a van den Bergh reaction of 1·0 mg. per 100 ml. plasma was found three days after dosing. On the fourth day after dosing symptoms of photosensitivity appeared. The œdematous swelling characteristic of photosensitivity disappeared by 7th April, 1942, but reappeared after the second dose of leaves on 8th April, 1942. The van den Bergh reaction was increased by the second dose of leaves, and reached 2·8 mg. per 100 ml. plasma on 10th April, 1942. Neither in sheep A40 nor sheep A19, dosed, respectively, berries and powdered wood, was there a van den Bergh reaction at any stage of the experiment and neither sheep showed any symptoms of photosensitization. Sheep A40 was scouring on 13th October, 1942, but no other adverse symptoms were noted in either sheep.

These results, in comparison with the known toxic and lethal doses of ngaio leaves, were taken as evidence of comparatively low toxicity of dried berries and wood.

M. serratum (Tasmanian Ngaio)

The amount of leaves available was small and it was therefore possible only to conduct an experiment on one sheep. Three doses were administered to this sheep; $5\frac{1}{2}$ g. per kilogram body-weight being the initial dose, followed nine days later by a dose of 10 g. per kilogram, and five days later again by a dose of 15 g. per kilogram body-weight.

The dose of $5\frac{1}{2}$ g. per kilogram produced no symptoms and there was no van den Bergh reaction; the dose of 10 g. per kilogram induced a van den Bergh reaction, the maximum reached being 1·0 mg. bilirubin per 100 ml. plasma, but no other symptoms; the dose of 15 g. per kilogram caused clinical icterus and a maximum van den Bergh reaction of 2·7 mg. bilirubin per 100 ml. plasma three days after dosing. Death occurred four days after the dose of 15 g. per kilogram body-weight. At autopsy the liver was found to be pale and somewhat necrotic; the alimentary tract was normal.

HISTOLOGICAL CHANGES

M. laetum

Leaves.—The liver was the only organ which showed recognizable pathological changes. The spleen and kidneys were not damaged.

Three phases of damage could be identified in the liver, and the different phases could be associated with different dose rates.

Single doses of 7·5 gm. per kilogram body-weight, which caused acute poisoning, produced acute congestion of the central vein of the lobule with dilatation of the sinusoids leading into the vein. In some lobules this congestion led to hæmorrhage. The cells in the hæmorrhagic area became degenerated and the nuclei showed some karyorrhexis.

After repeated doses of 4 g. to $6\frac{1}{2}$ g. per kilogram body-weight changes in the central area were less prominent, but the effects in the peripheral zone of the lobule were marked. The central area showed some pyknosis of nuclei of the parenchymal cells; in the peripheral zone the cytoplasm of the cells had become necrotic and nuclei were released. A ring of damaged cells thus appeared round each lobule.

The lining cells of the large bile duct were also affected; the cells first became elongated and the nuclei altered and, ultimately, the whole lining was sloughed.

Repeated small doses of ngaio, 1½ g. to 2½ g. per kilogram body-weight, did not cause recognizable changes in the central area. The damage to the peripheral zone was, however, even more accentuated. The damaged peripheral cells had become organized to form what appeared to be bile capillaries which in milder cases occurred in the portal area and in more advanced cases invaded the lobule. There was an increase in stroma to support the bile capillaries. The picture was similar to that of an old-standing case of facial eczema.

Berries produced no changes in the liver.

Wood induced a mild proliferation of bile capillaries.

M. serratum

In the one case of Tasmanian ngaio poisoning the liver changes were similar to those caused by repeated small doses of New Zealand ngaio.

RAT EXPERIMENTS

New Zealand ngaio was fed to rats, incorporated in the stock ration. The rates of feeding and effect on growth rate are shown in Table III.

TABLE III.—NGAIO LEAVES FED TO RATS FOR A FIVE-WEEK PERIOD

Percentage Ngaio in Ration.	Number of Rats.	Weight, in Grams.			Intake of Ngaio.	
		Initial.	Final.	Gain.	Per Rat/Day.	Grams/Kilogram average Body-weight.
6	6	101	171	70	1·2	9
12	6	104	156	52	2·6	20
15	4	138	202	64	4·2	25
20	4	106	138	32	3·8	31
25	4	105	84	−21	4·3	45
30	4	121	91	−30*	5·7	54

* Three weeks feeding period only.

The results show that ngaio leaves are much less toxic to the rat than to the sheep when comparison is made on the basis of weight of ngaio consumed per kilogram body-weight. In sheep a single dose of 7½ g. ngaio leaves per kilogram body-weight proved lethal; in rats, as shown in Table III, a daily intake of 30 g./kg. body-weight was maintained for five weeks without a lethal effect. The only observable effect was a subnormal rate of weight increase.

Rate of growth of rats fed ngaio was directly affected by rate of ngaio intake, and with the higher levels of ngaio intake there was actual loss of body-weight. Some deaths occurred in rats fed 25 per cent. and 30 per cent. of ngaio leaves in the ration.

Post-mortem examinations made on animals which died showed gastro-enteritis and changes in the liver; post-mortem examination of the remaining rats at the conclusion of the feeding period revealed changes only in the livers. The liver lobules were more defined than normal, the demarcation of the lobules being due to increase of interlobular tissue. The increase in interlobular tissue was greater the higher the intake of ngaio leaves.

On histological examination of the livers changes were found similar to those in livers of sheep fed repeated small doses of ngaio leaves.

Toxic Principle of Ngaio

Though determination of the nature of the toxic principle of ngaio leaves was of secondary importance to the main objects of this work, it was nevertheless considered of interest to make some observations on this aspect. These observations were limited to a study of the toxicity of the essential oil of ngaio. Supplies of this oil were made available through the generosity of Dr. F. H. McDowall, Dairy Research Institute, Palmerston North, and Mr. C. W. K. Brandt, Dominion Laboratory, Wellington.

The results of feeding trials with rats and sheep are recorded below.

Rats

Single doses of up to 0·6 g. per kilogram body-weight administered per stomach tube were non-toxic.

Sheep

Doses of 0·07, 0·1, 0·15, and 0·20 g. oil per kilogram body-weight were administered through the stomach tube, the oil being shaken up with water and the suspension washed through with several hundred millilitre of water.

The lowest dose, 0·07 g. per kilogram body-weight, produced no effect. No clinical effect was produced by a single dose of 0·10 g. per kilogram body-weight, but bilirubin was found in the blood plasma, the greatest concentration being 1·0 mg. per 100 ml. on the day after dosing.

Higher doses caused anorexia and icterus. Three sheep dosed 0·15 g. per kilogram body-weight all became sluggish and dull and declined food. Bilirubin was present in the blood plasma in all cases, the highest value recorded being 3·0 mg. per 100 ml. One sheep died forty-eight hours after dosing, and the other two were slaughtered after four days.

One sheep dosed 0·20 g. per kilogram body-weight died within fifteen hours of dosing.

The lethal dose to sheep of the essential oil of ngaio appeared to be in the region of 0·15 g. to 0·20 g. per kilogram body-weight.

Nothing could be seen on post-mortem examination of the sheep dosed 0·07 g. per kilogram body-weight, and in the sheep dosed 0·1 g./kg. body-weight there was congestion of the liver. Examination of sheep which had received higher doses revealed generalized icterus, generalized congestion of the organs with blood, and inflammation of the abomasum and intestines. In one case the abomasum and small intestines were normal, but there was hæmorrhage from the mucosa of the whole length of the colon and rectum.

Histological Changes

In all cases material was derived from animals shortly after dosing.

The spleen, kidneys, and lungs were congested with blood. The liver was intensely congested, the congestion being more marked in the portal areas and in the peripheral zone of the lobule.

Discussion

The clinical symptoms of ngaio poisoning in sheep observed in the present work—*viz.*, depression, anorexia, icterus, and photosensitivity—differ somewhat from those recorded in cattle poisoned by ngaio. Webster(4) and Aston(1, 2) stress more particularly the evidences of pain and severe constipation, while icterus and photosensitivity are not mentioned. In post-mortem examinations on cattle Webster(4) noted acute congestion of the kidneys, inflammation of the intestine, and hæmorrhages from the

abomasum, whereas the writers observed the most marked effect to be on the liver of the sheep. The intestines and organs other than the liver became involved only when higher doses were used. The differences between natural cases of poisoning in cattle and the experimental cases in sheep are probably due more to dose rate than to different responses of different species. Even in sheep the symptoms varied with dose rate; a high dose, for example, caused death before icterus or photosensitivity developed, and with low doses neither icterus nor photosensitization occurred.

Australian members of the genus *Myoporum* are toxic, and Hurst(5) has recorded a number of cases of poisoning in sheep and cattle by *M. acuminatum* and *M. deserti*. Reports by Legg and White(6) on *M. acuminatum* and Johnstone and Allen(7) on *M. deserti* show that the Australian species have a lower lethal dose—*i.e.*, are more toxic—for sheep than the *M. laetum* used in the present work; there is, however, a general similarity in the lesions produced by the three species. Jaundice was recorded by Johnstone and Allen as a symptom of poisoning by *M. deserti* and was associated with hæmolysis of red blood corpuscles. No hæmolysis occurred in poisoning by New Zealand ngaio, and the jaundice appeared to the writers to be due to obstruction of bile excretion by the congestion of the liver. Excretion of phylloerythrin was also prevented, and when a dose of ngaio was fed which caused severe liver damage but yet did not kill the sheep the accumulation of phylloerythrin was sufficient to cause acute photosensitization. The liver quickly recovered its capacity to excrete bile, and bilirubin and phylloerythrin had usually disappeared from the blood five to six days after dosing.

The occurrence of icterus and photosensitivity as a result of temporary dysfunction of the liver is of interest in a general way in respect to photosensitivity diseases.

The essential oil of ngaio possessed toxic properties similar to those of ngaio leaves, but appeared to have a more generalized effect on blood-vessels, causing hyperæmia and congestion of organs not affected by the lower doses of ngaio. It is probable that a more rapid absorption of the free oil than of the oil bound in ngaio leaves would account for its more generalized effect. McDowall(8) found from 0·12 per cent. to 0·30 per cent. of oil in fresh leaves; a dose of 0·15 g. oil per kilogram body-weight would therefore approximate to a dose of 12 g. dried leaves per kilogram body-weight. This is sufficiently close to the doses employed to suggest, along with the general similarity of symptoms, that the toxic principle of ngaio is the essential oil.

ACKNOWLEDGMENTS

The authors wish to record their indebtedness to Mr. N. T. Clare, M.Sc., of the Animal Research Station, Wallaceville, for examinations of blood and urine for porphyrins, and to Mr. W. H. Dawbin, M.Sc., for collection of some of the *Myoporum laetum*.

REFERENCES

(1) ASTON, B. C. (1923): *N.Z. J. Agr.*, *26*, 149.
(2) ——— (1934): *N.Z. J. Agr.*, *47*, 150.
(3) HANKIN, T. H. (1940): *N.Z. J. Agr.*, *61*, 360.
(4) WEBSTER, W. M. (1926): *N.Z. J. Agr.*, *33*, 102.
(5) HURST, E. (1942): "Poison Plants of New South Wales," Sydney, pp. 388–391.
(6) LEGG, J., and WHITE, C. T. (1941): *Aust. Vet. J.*, *17*, 104.
(7) JOHNSTONE, I. L., and ALLEN, G. H. (1944): *Aust. Vet. J.*, *20*, 227.
(8) MCDOWALL, F. H. (1925): *J. Chem. Soc.*, *127*, 2200.

THE DETERMINATION OF COPPER IN PASTURES AND LIVERS

By N. T. CLARE, I. J. CUNNINGHAM, and D. D. PERRIN, Department of Agriculture, Animal Research Station, Wallaceville

[*Received for publication, 5th February, 1945*]

Summary

A rapid procedure for the estimation of copper in pasture and liver samples is described. Interference by iron and manganese in the direct dithiocarbamate method for determination of copper is shown to be avoidable by maintaining a sufficiently high pH in the reaction mixture and by adding the sodium diethyldithiocarbamate as a dilute alkaline solution containing ammonium citrate. Dilute solutions of this reagent keep well at ordinary temperatures if made strongly alkaline. Results of recovery experiments and of comparison with the dithizone extraction method are given, and the method is shown to be satisfactory for pasture samples which contain high levels of iron and manganese as a result of soil contamination.

IN the course of studies on deficiency diseases at this laboratory it has been necessary to undertake determinations of copper in a considerable number of pastures and livers. These samples had to be obtained throughout New Zealand and brought to the laboratory, and problems, mostly associated with the avoidance of contamination during collection and transport, were encountered. Similarly, in the estimation of the copper, difficulties arose in the choice of a method which combined speed, convenience in handling many samples, and freedom from interference by other metals. In this paper is described the procedure for collection, preparation, and analysis of pasture and liver samples which meets these requirements.

COLLECTION AND PREPARATION OF SAMPLES

Pastures.—Since the copper content is lower when grasses become mature and fibrous, samples were collected when pastures were at the young growing stage and about 2 in. to 6 in. high. The usual method was adopted of clipping a number of small areas about 1 ft. square, and these were taken by random selection at intervals along a diagonal of the field to be sampled. A composite of these clippings formed the sample from one field.

In wet seasons care was necessary to avoid soil contamination from hoof-marks, worm casts, &c., and in dry seasons wind-blown dust sometimes caused contamination.

Difficulty was at first experienced in providing suitable bags for samples. Paper bags became moist and were liable to tear during transport, and new calico bags were found to contain a dressing material which contained enough copper to influence results for pasture samples left in the bags for some days. Eventually well-washed calico bags were employed with a grease-paper-bag lining which was renewed for each time of use. Samples could be transported satisfactorily in these bags.

In the laboratory the samples were dried in a current of warm air and ground to pass a screen with holes $\frac{1}{32}$ in. diameter in a C. and N. mill which had no brass or copper parts. In both the drying and the grinding it was important to ensure that no contamination occurred from the air intake. Ground samples were stored in acid-washed glass bottles.

Livers.—Wherever possible, the whole liver was obtained and forwarded to the laboratory in glass bottles without preservative. The liver was minced in a galvanized meat-mincer and a representative sample taken and dried at 100° C. in a hot-air oven with a forced draught. When a flat dish was employed to hold the liver, drying was completed in about twenty-four hours.

The dried sample was ground to pass a screen with holes $\frac{1}{64}$ in. in diameter in a C. and N. junior mill which contained no copper parts. The ground sample was collected directly into an acid-washed glass jar.

When prepared in the manner outlined, pasture and liver samples could be stored for long periods without deterioration.

DETERMINATION OF COPPER

The method of copper determination finally adopted is based on that of Eden and Green(1). In their procedure the sample is digested with a mixture of sulphuric, perchloric, and nitric acids, the digest is diluted with water and made alkaline with ammonia in the presence of ammonium citrate or pyrophosphate, and a yellow copper complex is formed by the addition of sodium diethyldithiocarbamate. This complex is then extracted into iso-amyl alcohol for colorimetric estimation. The purpose of the citrate or pyrophosphate is to prevent interference from iron and manganese. However, when this technique was applied to our samples it was found that a number failed to give reproducible results, particularly some which were unavoidably contaminated with small amounts of soil. Iron and manganese were found to be the elements causing this interference.

Copper can be separated from most of the other metals which form diethyldithiocarbamate complexes by preliminary extraction as the dithizonate at about pH 2–3(2, 3, 6), but this lengthy procedure is impracticable for our purposes in view of the number of estimations required. A study of the conditions under which iron and manganese interfere in the direct dithiocarbamate method was therefore made, and as a result a routine procedure which avoids such interference has been devised.

It has also been shown that the accuracy of the results is not impaired by the presence of a variety of other metals or by material precipitated during the analysis.

INTERFERENCE BY IRON

Both ferrous and ferric ions give with sodium diethyldithiocarbamate a dark-brown precipitate, partly soluble in iso-amyl alcohol, but frequently forming a layer at the alcohol water interface. At the end of the digestion of pastures the iron is in the ferric state, and the usual method of preventing interference is to suppress the ionization by forming non-ionized salts, ferric ammonium citrate or pyrophosphate, in the presence of excess ammonium ions (Eden and Green(1)). These authors point out, however, that if the reagent is added in a way which allows a local excess to develop the iron compound will be formed and extracted into the amyl alcohol. They recommend the use of 2·0 ml. of 0·5 per cent. aqueous reagent with continuous shaking of the tube during addition.

Our own experiments on the manner of addition of the reagent indicated that in samples containing iron considerable interference was possible if either the 2 per cent. or 0·5 per cent. neutral reagent was added without shaking, and some interference even when samples were shaken. The

extent of the interference in the latter case was found to depend not only on the concentration of iron, but also on the pH of the mixture, becoming less as the pH increased. Attempts were then made to decrease the "local excess effect" during addition of the reagent by diluting it, before addition, with an alkaline solution of ammonium citrate. When the 2 per cent. reagent was diluted with an equal volume of 50 per cent. ammonium citrate adjusted to pH 8·5, and samples were shaken during the addition, the iron colour in the amyl alcohol was often scarcely perceptible by eye, yet readings in the photoelectric absorptiometer usually represented several parts per million of copper. By decreasing the concentration of reagent to 0·2 per cent., diluting with an equal volume of citrate at pH 8·5, and adding the reagent with shaking, no trouble was encountered even when 10 ml. of this reagent mixture was added. Furthermore, it was quite safe to add 1 ml. of this dilute buffered reagent directly without shaking the tube.

Table I summarizes experiments in which the diethyldithiocarbamate reagent was added under various conditions of concentration and pH to solutions containing a high level of iron. The solutions were prepared by adding ferric ammonium sulphate to water containing 1 ml. concentrated H_2SO_4 and 2 ml. 50 per cent. ammonium citrate and neutralizing with ammonium hydroxide. The colour was extracted into 5 ml. iso-amyl alcohol and the light absorption determined in the photoelectric absorptiometer using the light filter employed in the determination of copper.

TABLE I.—IRON INTERFERENCE

(Amount of iron in 25 ml. = 10 mg., equivalent to 10,000 p.p.m. $Fe^{\cdots}$ on 1 g. sample of pasture)

Reagent (Amount, Concentration, Manner of Addition, &c.).	Colour* in Iso-amyl Alcohol at pH			
	6·5.	7·5.	8·5.	9·5.
0·5 ml. 2 per cent., neutral, with shaking	Very high	45	30	25
0·5 ml. 2 per cent., neutral, without shaking	,,	+++	+++	+++
2 ml. 0·5 per cent., neutral, with shaking	,,	+	25	15
2 ml. 0·5 per cent., neutral, without shaking	,,	Very high	20	+
0·5 ml. 2 per cent. plus 0·5 ml. citrate pH 8·5, with shaking	++	30	20	10
0·5 ml. 2 per cent. plus 0·5 ml. citrate pH 8·5, without shaking	++	30	Very high	10
0·5 ml. 0·2 per cent. plus 0·5 ml. citrate pH 8·5, with shaking	++	Nil	Nil	Nil
0·5 ml. 0·2 per cent. plus 0·5 ml. citrate pH 8·5, without shaking	++	Nil	Nil	Nil
5 ml. 0·2 per cent. plus 5 ml. citrate pH 8·5, without shaking	++	Nil	Nil	Nil

* The figures represent the p.p.m. copper-equivalent of the colour produced by the iron. "Very high" and symbols +++ to + indicate colours too great to read conveniently in the photoelectric absorptiometer—*i.e.*, equivalent to more than 50 p.p.m. Cu.

These results illustrate clearly that the interference due to iron is governed by the pH of the solution and by the nature of the added mixture containing the reagent. By adjusting the solution to a pH above 7·5 and by adding a 0·1 per cent. solution of reagent in 25 per cent. ammonium citrate at pH 8·5, interference due to iron is completely eliminated even when the amount present is much greater than is likely to be met within practice.

The photoelectric absorptiometer in use is one made in this laboratory and uses a single Weston photronic cell in a circuit of the Evelyn type. The absorption cell is a 20 mm. cell with plane faces, and the only light filter is a 5 per cent. aqueous solution of copper sulphate. Restriction of the light to a narrower band of wave-lengths is not practicable with materials at present available. The observation that a scarcely visible iron colour in the iso-amyl alcohol layer was recorded as an appreciable copper value in this absorptiometer suggested that the photocell is particularly sensitive to light of wave-lengths absorbed by the iron diethyldithiocarbamate complex. As an indication of the error possible in visual photometry, the copper equivalents of some of the solutions referred to in Table I were determined with a Zeiss Pulfrich photometer. A solution reading as 10 parts per million in the photoelectric instrument gave values of 2·5 parts per million for filter S47, 4·8 for S50, and 11·5 for S53. Appreciable error may occur, therefore, even when the Pulfrich photometer is used.

INTERFERENCE BY MANGANESE

Some of the samples which did not give concordant duplicate analyses appeared, from the colour of the digest after making alkaline, to contain only small amounts of iron. The foreign colour which appeared in the iso-amyl alcohol in these cases differed from the iron complex in that it tended more towards a pink shade, faded rapidly, and was discharged by addition of more ammonium hydroxide. The samples in which it occurred were often high in manganese, and addition of manganese to blank preparations showed that it produced a colour with these characteristics, although not on all occasions. Interference by manganese is prevented (according to Eden and Green(1)) in the same way as for $Fe^{\cdots}$ ions, by suppressing the ionization with citrate in presence of ammonium ions. As with iron, a local excess of reagent leads to formation of the extractable coloured complex. Experiments similar to those reported in Table I, using manganese sulphate, showed that the interference due to manganese also is influenced by the pH of the solution, and that the use of 0·5 ml. of 0·2 per cent. reagent diluted with an equal volume of 50 per cent. ammonium citrate will eliminate such interference, provided the pH is over 8·5. Such a procedure is safe with a level of manganese equivalent to 10,000 parts per million in a 1 g. sample of pasture.

As the result of the foregoing experiments it was decided to use 1 ml. of a solution containing 0·1 per cent. of the reagent and 25 per cent. ammonium citrate at a pH greater than 8·5 in each determination. This amount of reagent is theoretically sufficient to combine with 0·185 mg. copper, and in practice has been found to obtain complete recoveries with over 0·150 mg. The amount of copper estimated in 1 g. of pasture is usually of the order of 0·005 mg. to 0·02 mg., and only rarely exceeds 0·03 mg., so that 1 ml. of 0·1 per cent. solution provides ample reagent.

INTERFERENCE OF OTHER METALS

Of the metals which react with diethyldithiocarbamate, the following give white precipitates: Cd, $Sn^{\cdot\cdot}$, Pb, Zn, Hg, Ag, Cr. Apart from the fact that most of these do not occur in appreciable amounts in pastures and livers, any possible interference by introducing turbidity into the amyl alcohol phase in the method is eliminated at the filtration stage. Bismuth gives a coloured complex soluble in amyl alcohol, but allowance can be made for this by the modification used by Piper(3), as indicated later in this

paper. Although cobalt and nickel also form coloured extractible complexes, results given by Drabkin(5) indicate that 10 parts per million of both these metals in a sample would not produce significant error.

Solutions containing some of these metals were tested in our experiments, and under normal conditions chromium (= 400μg./g. of sample) lead (30,000 μg.), silver (100,000 μg.), zinc (1,000 μg.), and mercury (10,000 μg.) gave clear, colourless amyl alcohol filtrates. A solution containing 20 μg. of copper gave recoveries of 20 μg. when 10 μg. of cobalt and 10 μg. of nickel were both present, and when 50 μg. of each of these were added separately.

Since these amounts all greatly exceed those likely to be found in biological material, it is concluded that these metals will not interfere in the determination of copper in such materials.

Even the interference from bismuth was less than anticipated; 200 μg. of bismuth gave a yellow colour with greenish tinge in the amyl alcohol, but this corresponded to only 0·5 μg. of copper when read in our photoelectric absorptiometer, and to 3 μg. on matching with filter S47 of the Pulfrich photometer. (Such quantities would be equivalent to 0·5 p.p.m. and 3·0 p.p.m. in the analysis of 1 g. of pasture.)

RECOVERY OF COPPER IN PRESENCE OF SILICA AND PHOSPHATE PRECIPITATES

Piper(3) prefers dithizone for separation of copper, because diethyldithiocarbamate does not entirely extract this metal from the aqueous phase in the presence of silica. According to Bendix and Grabenstetter(6), some copper is retained by precipitated phosphates. Recovery experiments made early in this investigation indicated that any errors due to non-quantitative extraction of copper from pasture and liver solutions for either of these reasons was negligible. However, the point was further studied in the following way: to solutions containing known amounts of copper were added calcium chloride (0·2 g.), sodium silicate (SiO_2 = 0·1 g.), and sodium phosphate (Na_2HPO_4, 0·3 g.), the mixtures were then boiled down with 1 ml. of sulphuric acid and the copper estimated by the usual process. The copper content of each aliquot of standard solution was 8·3 μg., and was not altered by addition of either silica or phosphate alone, but was raised to 8·9 μg. by calcium chloride alone, owing to copper in this reagent. In the presence of the calcium, silica, and phosphate together the recovery was 8·7 μg. Similar results have been obtained by repetition of this experiment. The amounts of calcium phosphate and silica precipitated in these trials were always much greater than those seen in pasture solutions; therefore it is concluded that significant error will not arise through retention of copper in these precipitates.

STABILITY OF THE REAGENT

Sodium diethyldithiocarbamate in neutral aqueous solution (the condition in which it is generally used(1, 2)) undergoes decomposition which is hastened by acid. Piper(3) indicates that the solution should be kept in the dark. To avoid making up fresh reagent frequently, Moir and Andrews(4) add it in the solid form, but this procedure is tedious when many analyses are undertaken and also may increase the possibility of iron and manganese interference through local excess as the reagent dissolves. With the use of more dilute reagent solutions such as we suggest, the risk of the amount of the dithiocarbamate becoming too small to combine with all the copper is

increased. To test the stability of the reagent under working-conditions 0·1 per cent. solutions were made up as follows :—

(i) Glass-distilled water, pH about 5·5. (Owing to hydrolysis of the reagent, this solution rapidly became alkaline, so that solution (i) had a higher pH than solution (ii) during the experiment):

(ii) Ammonium citrate solution adjusted to pH 7 :

(iii) Strongly ammoniacal solution (15 ml. of 0·880 ammonium hydroxide plus 85 ml. of glass-distilled water).

These were allowed to stand in clear glass flasks on the laboratory bench and in brown bottles kept in the dark and tested at intervals for three weeks, the room temperature being usually less than 15° C. At the end of this time 1 ml. portions of all three solutions still recovered 0·025 mg. of copper from a solution containing that amount. Aliquots of 0·1 ml. from solutions (i) and (iii) also gave full recovery on 0·01 mg. copper, whereas (ii) gave only 40 per cent. recovery.

At the end of three weeks the solutions in clear glass flasks were placed in midday winter sunshine for four hours, the temperature of the solutions not exceeding 20° C., without altering the recoveries. However, heating at 25–30° C. for four hours in a water-bath in dull light caused considerable decomposition of solutions (i) and (ii), but did not measurably affect (iii).

It was concluded, therefore, that under ordinary laboratory conditions dilute reagent solutions will remain stable for at least three weeks if strongly alkaline. These experiments suggest, also, that light does not greatly influence the decomposition ; nevertheless, it is our practice to keep the reagent solution in dark bottles.

DESCRIPTION OF METHOD

Pastures.—About 1 g. of dried, finely ground pasture is weighed into an 8 in. by 1 in. Pyrex test-tube marked at 25 ml., three glass beads are added, and then a mixture of sulphuric and perchloric acids is delivered into the tube from a 5 ml. automatic measuring device. This mixture consists of 1 ml. perchloric acid (60 per cent.), 1 ml. sulphuric acid, and 3 ml. of copper-free water. One ml. of redistilled nitric acid is then added from a teat-pipette and the open tube placed on a microdigestion rack over a small flame. The mixture is heated fairly gently until boiling, and then a further 1 ml. of nitric acid is added slowly. When the initial vigorous frothing ceases and the digestion is proceeding more quitely, the burners are turned up to the maximum. More nitric acid is added when the digestion begins to blacken and give off white fumes, two further 1 ml. additions usually being required. After the digest is clear and excess perchloric acid is coming off as fine bubbles, a few more drops of nitric acid are often added. In order to complete the digestion the boiling is continued another fifteen minutes, the volume then being about 1 ml. This final stage is necessary to ensure thorough destruction of organic matter, which otherwise gives a yellow colour upon neutralization. If enough manganese is present, the digest may assume the permanganate colour. Digestion is generally complete when this colour appears.

When sufficiently cool, the tubes are removed and washed down with 10 ml. to 15 ml. of copper-free water. Two ml. of 50 per cent. ammonium citrate are added, then, after mixing, 5 ml. of ammonium hydroxide (S.G., 0·880). The pH of the solution should now be not less than 8·5 ;

5 ml. of ammonia is usually sufficient for this purpose, but if the digestion has not been boiled down far enough, or if much ammonia is lost by overheating during neutralization, the required pH may not be reached. One drop of 0·2 per cent. phenol phthalein may safely be added to check the pH, since this indicator does not give a coloured solution in amyl alcohol.

After cooling, the mixture is made up to 25 ml., and 5 ml. of iso-amyl alcohol (B.P., 128–32° C.), accurately measured, is added. The tube is now stoppered with an acid-washed rubber bung and shaken ten to twenty times. Any yellow colour due to residual organic matter is extracted into the amyl alcohol layer at this stage, in which case the digestion should be repeated with a fresh aliquot of pasture (but see note 4).

If the amyl alcohol is clear, 1 ml. of the diethyldithiocarbamate reagent is added and the mixture shaken vigorously fifty to sixty times. When the layers separate, the amyl alcohol is removed with a teat pipette and filtered into a vial through acid-washed paper to remove traces of moisture. Finally the absorption of the amyl alcohol is read in the photoelectric absorptiometer.

Livers.—The procedure is essentially the same as for pastures. The weight of liver digested varies, however, about 0·5 g. being taken when a normal copper content is expected, while 1 g. or more is taken from livers of low copper content. It is frequently necessary, with livers of unknown copper content, to run a preliminary single determination to obtain an indication of the order of the content of copper.

The acid digestion mixture is the same as for pastures, but it is advisable to boil livers for a short time with sulphuric acid, perchloric acid, and water before any nitric acid is added. In this way troublesome frothing is avoided.

The 8 in. by 1 in. Pyrex test-tubes used for liver analysis are marked at 25 ml. and accurately graduated at 50 ml. and 75 ml.

After completion of digestion, the samples of livers which contain 30 p.p.m. or less of copper are completed as for pastures. With those livers which contain a higher amount of copper it is necessary to dilute with copper-free water to 50 ml. or 75 ml. and take an aliquot of this solution for the final stage of colour development. When an aliquot is taken into a fresh tube, concentrated H_2SO_4 is added so as to bring the content of H_2SO_4 up to 1 ml. The blank solution is treated in the same manner. From this point the analysis is completed as for pastures.

It sometimes happens that the amount of copper in the aliquot is too high for reliable measurement in the absorptiometer. In such cases it has been found satisfactory to add a greater volume of amyl alcohol so as to dilute the colour; 1 ml. extra reagent is added for each 5 ml. extra amyl alcohol used. Allowance for this dilution by amyl alcohol is, of course, made in the final calculation. Where more than 10 ml. extra of amyl alcohol is necessary, the practice is followed of confirming the figure by taking a fresh smaller aliquot or making a fresh digestion.

In the case of both pastures and livers a dry-matter determination is made on a sample taken from the jar at about the same time as the sample for digestion. Allowance for moisture content is made in calculating the result.

REAGENTS

Ammonium Citrate.—It has been necessary to prepare and purify this reagent in the laboratory, the procedure being as follows: 435 g. of citric

acid is dissolved in glass-distilled water and made just alkaline to bromthymol-blue (external indicator) with 0·880 ammonia. One millilitre of 2 per cent. sodium diethyldithiocarbamate (in water containing a little NH_4OH) is added and the preparation shaken in a separating funnel with iso-amyl alcohol to remove the copper complex. Extraction with the alcohol is repeated until the top layer is colourless, then a few drops more reagent is added to make sure that all copper has been removed. The solution is next made acid (pH 5) with 50 per cent. H_2SO_4 and again shaken (twice) with amyl alcohol to take out any reagent which has not combined with copper. Removal of excess reagent is necessary to enable the test for undigested organic matter to be made. Ammonium hydroxide is added to bring the pH to 8·5 and the volume made up to 1 litre. The solution is tested for the presence of both copper and the diethyldithiocarbamate reagent before being put into use.

Sodium Diethyldithiocarbamate.—In 85 ml. copper-free water 0·2 g. is dissolved and 15 ml. NH_4OH is added. This solution is kept in a brown bottle, and just before use is diluted with an equal volume of ammonium citrate.

NOTES ON THE METHOD

1. All samples are analysed in duplicate. A blank consisting of the reagents only is included in each batch of twelve samples.

2. The same teat pipette is used throughout the series for removing the iso-amyl alcohol, those samples with the least colour in the alcohol being separated first. They are pipetted into the photometer cell in the same order.

3. To test for bismuth (which also forms an extractable yellow complex), the amyl alcohol may be returned to the tube after matching, 1 ml. of fresh 10 per cent. KCN added, and the tubes shaken. The copper complex is thus destroyed, any residual colour indicating the presence of bismuth (Piper(3)). This procedure has been used with over one hundred samples, including all the areas regularly sampled, and no bismuth has yet been encountered.

4. The colour due to incomplete digestion also is not discharged by potassium cyanide; it is often increased, so that attempts to correct for the incomplete digestion colour by measuring the absorption after addition of cyanide are not reliable. (It follows that the test for bismuth will be misleading if this colour is present.) Allowance can be made for the incomplete digestion colour by removing the amyl alcohol after extracting this colour, measuring its intensity of absorption, and then returning the amyl alcohol to the extraction tube before adding the diethyldithiocarbamate reagent. For examples the following samples can be quoted, the first figure in each set representing a completely digested aliquot, the second an aliquot in which allowance had to be made for incomplete digestion, and the third the value for this aliquot after correcting for the foreign colour—pasture 1008: 6·4, 7·4, 6·5; pasture 1021: 4·6, 5·6, 4·6; pasture 1053: 8·6, 10·0, 9·3. In practice, however, it is desirable to repeat all digestions which show any trace of colour in the amyl alcohol layer before addition of the reagent.

5. Whatman No. 40 or No. 50 filter papers, 5·5 cm., are used. These are soaked in 5 per cent. (v/v) nitric acid overnight, then in repeated changes of glass-distilled water, followed by 10 per cent. Analar ammonium hydroxide, and finally washed with glass distilled water. They are dried at 80° C. The papers may safely be rewashed and used several times. All glassware is washed with 5 per cent. nitric acid, followed by copper-free water.

The possibility of loss of copper diethyldithiocarbamate by absorption on the filter paper was examined on several occasions by filtering an amyl alcohol extract through separate papers and determining the copper content of an aliquot after each filtration. No change of concentration has been observed even after twelve filtrations.

6. Homogeneity of samples is ensured by the fineness of grinding—in the mill the whole pasture sample passes a screen with holes $\frac{1}{32}$ in. in diameter and the liver sample passes a screen with holes $\frac{1}{64}$ in. in diameter. That a 1 g. aliquot is adequately representative of the ground material is demonstrated by the good agreement generally given by duplicates. For example, in the results for forty-eight consecutive pasture

samples the greatest difference between duplicates was 0·8 p.p.m., the mean difference 0·3 p.p.m., and the distribution of these differences was : 0–0·3 p.p.m., 26; 0·4–0·5 p.p.m., 15 ; 0·6–0·8 p.p.m., 7. As a further test of the sampling technique, the copper content of some pastures has been determined repeatedly, the following results being typical: No. 738, 9 analyses, range 8·0–8·3 p.p.m., mean 8·1 p.p.m. ; No. 1079, 6 analyses, range 11·1–11·5 p.p.m., mean 11·3 p.p.m.

7. Micro digestion racks were made by supporting two 4-in.-wide sheets of asbestos 6 in. apart by wooden ends. In the top sheet, holes 1¼ in. diameter and 4 in. apart were bored, and in the bottom sheet corresponding holes were ¾ in. diameter. The tubes slip through the top hole and rest on the bottom hole, and the holes are so disposed that the tube is held at an angle of approximately 20° to the vertical. Heat is applied through the holes in the bottom sheet.

8. With this method it is possible for one worker to complete the analysis of twenty-four pasture samples in duplicate in eight working-hours. Liver samples take slightly longer as a rule, owing to necessity of making dilutions.

RECOVERY OF COPPER ADDED TO PASTURE

To test the accuracy of the method, recovery trials were made on pasture to which a known amount of copper had been added. Two of the samples chosen (E1175 and E1176) were ones which were known to be low in copper and to contain much manganese. Results are given in Table II.

TABLE II.—RECOVERY OF ADDED COPPER

No.	Mg. Cu added to 1 g. Pasture.	Cu found (p.p.m.).	Cu calculated (p.p.m.).
E1175	Nil	2·0	..
	0·002	4·3	4·0
	0·004	6·2	6·0
	0·006	8·0	8·0
E1176	Nil	1·6	..
	0·002	3·7	3·6
	0·004	5·7	5·6
	0·008	9·5	9·6
F150	Nil	1·6	..
	0·0043	5·8	5·9
	0·0086	10·3	10·2
E1449	Nil	9·3	..
	0·0043	13·4	13·6
	0·0086	17·4	17·9
E1495	Nil	18·4	..
	0·0043	23·0	22·7
	0·0086	26·2	27·0
E801	Nil	3·2	..
	0·0042	7·2	7·4
	0·0084	11·4	11·6
E794	Nil	9·7	..
	0·0042	14·0	13·9
	0·0084	18·0	18·1
E787	Nil	25·6	..
	0·0042	30·0	29·8
	0·0084	33·7	34·0

In further trials the iron and manganese in the samples were greatly increased by addition of solutions of ferric ammonium sulphate and manganese sulphate to 1 g. aliquots of pastures and the analyses carried through in the usual way (Table III). The original pasture samples contained amounts of iron ranging from 50–80 p.p.m., and of manganese from 150–300 p.p.m. Addition of 1 mg. of these metals to the pasture aliquots increases these levels by 1,000 p.p.m.

TABLE III.—RECOVERIES IN PRESENCE OF ADDED IRON AND MANGANESE

—	Cu, in p.p.m. (Mean of Triplicate Analyses).		
Sample No.	801.	794.	787.
Pasture alone	3·2	9·7	25·6
Plus 1 mg. Fe	3·3	9·5	25·5
Plus 1 mg. Mn	3·2	9·5	26·1
Plus 1 mg. Fe + 1 mg. Mn	3·1	10·0	25·8
Plus 1 mg. Fe + 1 mg. Mn + ·0042 mg. Cu—			
Found	7·5	13·9	30·2
Calc.	7·4	13·9	29·9

These results show that, under the actual working-conditions described, amounts of iron and manganese of the order of 1,000 p.p.m. do not interfere or affect the recovery of added copper.

COMPARISON WITH DITHIZONE METHOD

As a final test the method was compared with that recommended by Piper(3) in which a preliminary extraction is made with dithizone. With five of these pasture samples the estimations were made in triplicate on separate aliquots of each sample; with two pasture samples (882 and 647) solutions obtained by digestion of 2 g. portions of each sample were divided into two portions, one being treated in the usual way, the other by Piper's procedure; for the liver samples duplicate 1 g. lots were digested, and the digests divided into two portions, one of which was analysed by each method. Any slight differences inherent in the taking of aliquots of the ground material were thus eliminated in the two pastures and in all the livers. Results are shown in Table IV.

TABLE IV.—DIRECT METHOD COMPARED WITH PIPER'S DITHIZONE METHOD

Pastures.				Livers.			
Sample No.	Copper, in p.p.m.		Iron (p.p.m.).	Sample No.	Copper, in p.p.m.		Iron (p.p.m.).
	Direct Method.	Dithizone.			Direct Method.	Dithizone.	
801	3·2	3·1	50	448	4·6	4·9	370
794	9·7	10·2	80	977	9·9	9·7	1,400
882	6·2	6·6	60	989	2·3	2·6	650
647	7·6	7·4	..	992	2·4	2·4	1,600
1055	10·1	10·7	..	1114	7·5	7·6	1,100
281	9·5	9·5	..	1135	3·5	3·5	6,200
415	12·3	12·0	..	EB334	254	266	..

Agreement between the two methods is seen to be very close; there is certainly no evidence that the direct method fails to eliminate any substance which by its interference might lead to high values.

DISCUSSION

Methods for copper estimation in which the metal is first extracted from the test solution with dithizone and then estimated colorimetrically as the diethyldithiocarbamate complex have come to be regarded as superior to those which employ either of the reagents alone. Preliminary extraction with dithizone provides a solution comparatively free from other metals which form carbamate complexes, while it is claimed(6) that the dithizone also extracts the copper more completely from solutions containing precipitated phosphates. Against such advantages are the time consumed in the dithizone extraction process, the need for exhaustive shaking(6), and the necessity of making transfers to several different vessels, whereby the risks of loss and of contamination are both increased. Furthermore, the dithizone extract at pH 3·0 is, according to Piper(3), not entirely free from iron, so that precautions to avoid interference by this metal must in any case be taken at a later stage. Methods such as that of Bendix and Grabenstetter(6), which employ dithizone alone, are also lengthy, and in addition the instability of the dithizonate colour and its dependence on carefully controlled conditions introduce uncertainties in the colorimetric estimation.

The direct dithiocarbamate method described in this paper is rapid and requires only easily manipulated apparatus. The experiments recorded here, as well as experience gained in the handling of over two thousand pasture samples and eight hundred livers (in eight months), indicate that it is not liable to interference from metals likely to be encountered in biological material. Likewise, losses due to silica or phosphate precipitates were not found to occur. The method is sufficiently sensitive and yields results which compare favourably with those obtained on the same samples by the dithizone extraction method of Piper. Owing to its freedom from interference by iron and manganese the method may safely be applied to samples which, because of weather and pasture conditions at the time of collection are unavoidably contaminated with small amounts of soil.

Experience with the method as applied to materials other than pasture, liver, kidney, and spleen has been limited. It has been found, however, that copper can be determined quickly and rapidly in organic materials such as rubber and in mineral substances such as soils. The bases of judgment as to accuracy were concordant values for duplicate samples and good agreement with results obtained when a preliminary separation by dithizone was carried out.

It is of interest to record that dry ashing of pastures in silica vessels sometimes gave correct values, but frequently gave low values as judged by determinations made on the same samples using the method described in this paper. When pastures were ashed in the presence of magnesium nitrate as recommended by Van Niekerk(7), the result was found to agree well with figures obtained by the wet ashing process described. Ashing by the Van Niekerk method was, however, extremely tedious and there was always the risk of loss of the sample through too violent combustion—all dry ashing methods were in fact, found to be very much slower than the wet ashing procedure.

REFERENCES

(1) EDEN, A., and GREEN, H. H. (1940): *Biochem. J.*, *34*, 1202.
(2) SYLVESTER, N. D., and LAMPITT, L. H. (1935): *Analyst*, *60*, 376.
(3) PIPER, C. S. (1942): "Soil and Plant Analysis" (University of Adelaide).
(4) MOIR, G. M., and ANDREWS, E. D. (1940): *N.Z. J. Sci. & Tech.*, *21*, 249A.
(5) DRABKIN, D. L. (1939): *J.A.O.A.C.*, *22*, 320.
(6) BENDIX, G. H., and GRABENSTETTER, D. (1943): *Ind. Eng. Chem., Anal. Ed.*, *15*, 649.
(7) VAN NIEKERK, P. Le R. (1937): *Onderstepoort J. Vet. Sci.*, *9*, 623.

CAPE TULIP

By A. J. HEALY, Botany Division, Plant Research Bureau, Department of Scientific and Industrial Research

[*Received for publication, 12th October, 1944*]

Summary

The occurrence of one-leaved cape tulip (*Homeria collina* (Thunb.) Vent.), a South African species, is noted as an established garden escape in one locality in New Zealand. A description of the plant is given, together with life-history. The plant is toxic to live-stock and human beings overseas, and suspected instances of poisoning of stock have occurred at Hamilton Bay. Control is by digging up scattered plants, and with larger blocks several applications of arsenic pentoxide. The use of afforestation is suggested.

HISTORICAL

IN September, 1943, a specimen of this plant was submitted for identification by Mr. H. C. Hope, Hamilton Bay, French Pass, through the Instructor in Agriculture, Blenheim. The specimen was determined as one-leaved cape tulip (*Homeria collina*). The information forwarded at that time indicated that several acres were infested with the plant. Justifiable concern as to the future of the weed has been expressed by individual farmers and farmers' organizations in that locality. Recently a visit was made to the Hamilton Bay (Fig. 1) locality (30th August, 1944, to 31st August, 1944) to determine the actual area involved, any particular features of the infestation, and possible means of control under the particular conditions.

It is evident that the weed was introduced to the locality as a garden plant, as has been the instance in various Australian occurrences. It was planted in the garden of an old house at Hamilton Bay, and spread from there to adjacent pasture land. It has spread from the original focus about the old house to an adjacent ridge and has continued to move outwards. Prior to the present occupier of the property coming in six years ago, pigs had been run on the block where the tulip occurred, and there was apparently a marked increase in spread after this period. In 1940 the area of heaviest infestation was fenced off so that stock could be kept off, since the stock had been noted to scour profusely when allowed access to the weed.

BOTANICAL CHARACTERS

The one-leaved cape tulip belongs to the Iridaceæ, a family whose members are commonly grown in gardens. The plant belongs to a genus of some twenty-five species, endemic in South Africa. It is related to several common garden escapes which occur in New Zealand—*Watsonia*, *Iris*, *Antholyza*, *Sparaxis*, and *Ixia*.

It has a globose corm (" bulb "), ¾ in. to 1 in. in diameter, covered by thick, dark-brown, latticed sheaths. A single, ribbed, linear leaf 1 ft. to 2 ft. long and ¼ in. to ½ in. wide is produced from the corm, and in August a single stem, shorter than the leaf, is produced (Fig. 2). Two to four clusters of flowers enclosed in spathes are borne on each stem. The flowers are 1½ in. to 2 in. in diameter, the petals varying in colour from orange-scarlet to salmon-pink, with the basal parts yellow. The seed capsule is narrow cylindric, more than 1 in. long.

LIFE-HISTORY

Investigational work on this aspect has been carried out, and the following account is taken from Clarke (1939). A longitudinal section through the base of a flowering plant shows that the lateral corms arise singly in the axils of the corm scales. Of the two axillary corms shown at the base of the plant (Fig. 2), the larger one will grow, during the next season, into a flowering plant similar to the one figured, whereas the smaller one produces an individual which will not flower until the following year.

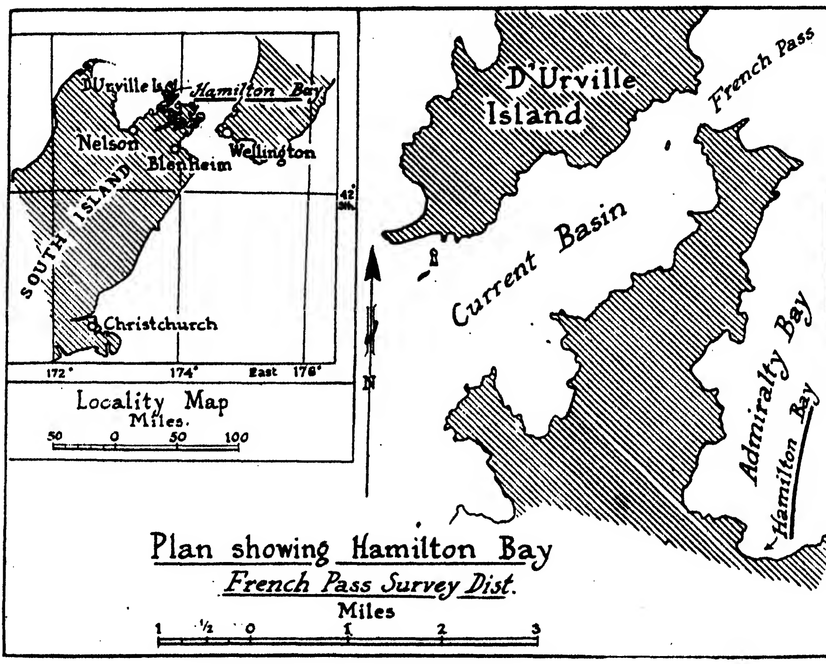
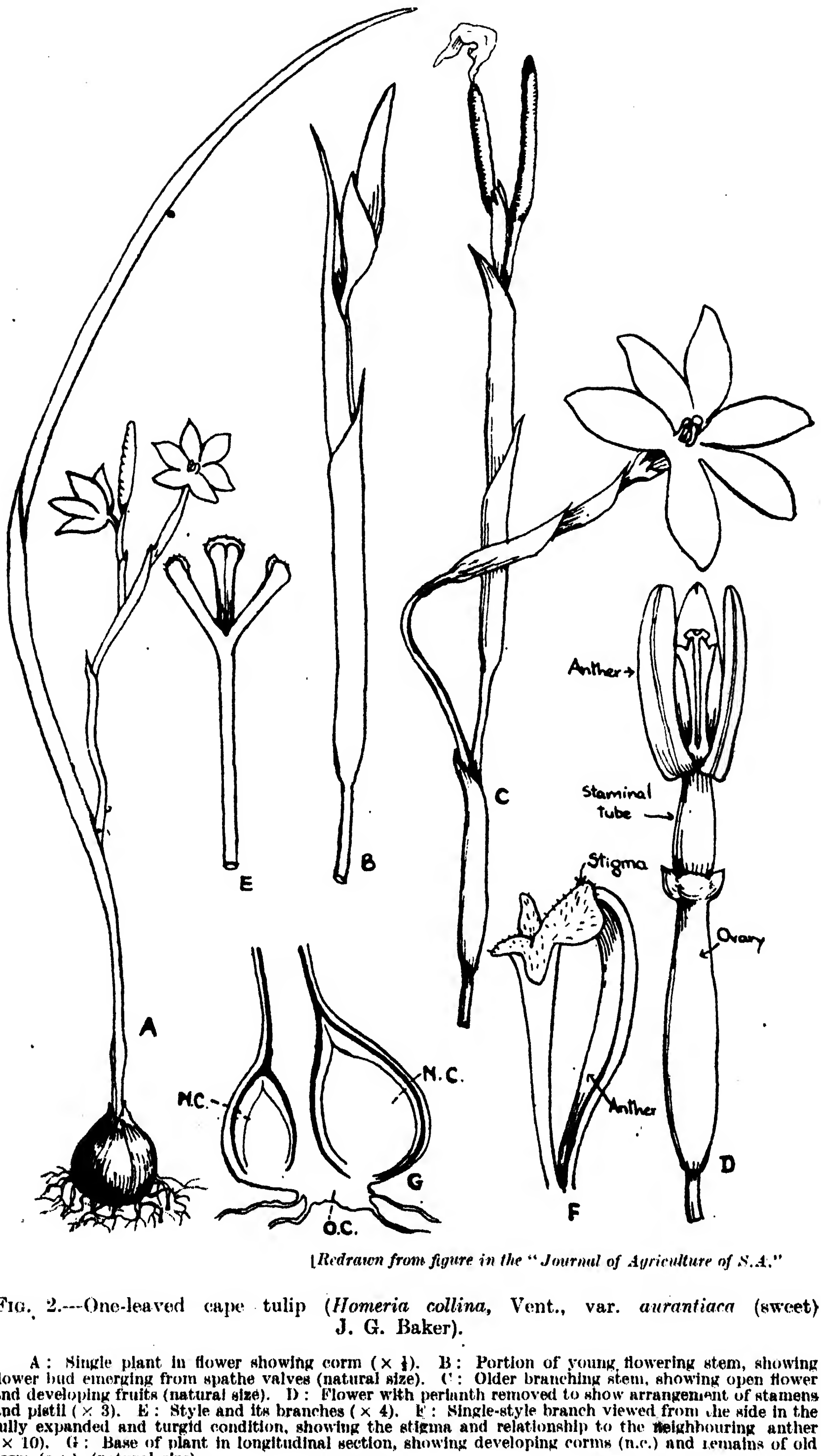


FIG. 1.

PROPAGATION AND MEANS OF DISPERSAL

The plant spreads by means of seeds, which are light, and according to Clarke (1939) are carried by the wind. Observations in the field at Hamilton Bay show the plant to occur along sheep-tracks, often a considerable distance from the main patches, and indicate that seeds are carried by stock, either in mud in the hooves and/or in the fleeces. The thickening-up of an existing stand of the weed comes about by the underground corm development and, according to my observations, by seed also, since amongst the large plants there were large numbers of seedlings, some with the seed still attached. The grazing of pigs, as mentioned earlier, would tend to spread the underground corms by the rooting, and not only thicken up the pre-existing stand, but assist in spread to adjacent land.

The manner in which the Hamilton Bay infestation has formed a dense association with the virtual exclusion of other pasture species in the thickest patches, and the extent of its spread to points remote from the dense blocks, indicate that there is a definite necessity for eradication of the plant to be attempted, otherwise it will spread more and more into at present non-infested country.



[Redrawn from figure in the "Journal of Agriculture of S.A."

FIG. 2.—One-leaved cape tulip (*Homeria collina*, Vent., var. *aurantiaca* (sweet) J. G. Baker).

A : Single plant in flower showing corm (× ½). B : Portion of young flowering stem, showing flower bud emerging from spathe valves (natural size). C : Older branching stem, showing open flower and developing fruits (natural size). D : Flower with perianth removed to show arrangement of stamens and pistil (× 3). E : Style and its branches (× 4). F : Single-style branch viewed from the side in the fully expanded and turgid condition, showing the stigma and relationship to the neighbouring anther (× 10). G : Base of plant in longitudinal section, showing developing corms (n.c.) and remains of old corm (o.c.), (natural size).

DISTRIBUTION

At present the occurrence at Hamilton Bay, French Pass, is the only locality in New Zealand where the plant is known (see Fig. 1). The area involved is some 35 acres, of which 3 acres to 4 acres have a dense association of *Homeria*, with scattered plants and small patches over approximately 30 acres.

TOXICITY OF ONE-LEAVED CAPE TULIP

The poisonous nature of the plant is recorded by both South African and Australian workers, and all stress the menacing character of the species. Australian workers (Clarke, 1939; Meadley, 1943; Carne, Gardner, and Bennetts, 1926) mention that stock accustomed to grazing on areas infested with cape tulip are infrequently affected, probably because they avoid grazing the plant, or, as one worker suggests, they attain some degree of immunity from the toxicity, whereas most serious mortality occurs amongst stock that are brought into infested country from non-infested localities (Department of Agriculture, New South Wales, 1935).

Steyn (1934) states that the corm contains a glucoside which has a similar action to that of digitalis on the heart, raises the blood-pressure, and constricts the blood-vessels. Poisoning of Natives in South Africa is described, and a number of cases of stock poisoning are cited—it is known as "tulp poisoning" there, the name apparently being a corruption of tulip. Steyn fed 220 grammes of fresh corms and leaves of plants at flowering stage to a mature sheep, and death occurred about thirty hours after administration.

Hurst (1942) notes that the flower heads, leaves, and corms are toxic, and records instances where the plant was toxic to cattle.

Carne, Gardner, and Bennetts (1926) record the death of seven cattle beasts on one property due to eating the weed.

The symptoms are described by Clarke (1939) as partly those of an acute gastro-intestinal irritant, and partly those of a cerebral depressant or narcotic. Examples of the first are abdominal pain, diarrhœa, and, with ingestion of much green leafy material, distension of the stomach with gas, the symptoms increasing in severity and resulting in colic, frequent scouring, great weakness, and prostration. The nervous symptoms are indicated by dullness and depression. Death may occur rapidly, within twelve hours or less, of ingestion, or the animals may linger for several days. Carne, Gardner, and Bennetts (1926) describe lesions of intense gastro-enteritis and cardiac hæmorrhages revealed by post-mortem examination of a bull poisoned by cape tulip.

At the Hamilton Bay occurrence, actual deaths due to poisoning are not certain, although several deaths probably due to this cause have happened. Severe scouring of sheep from other parts of the property when pastured on the cape-tulip-infested block has been noted.

These data indicate that all portions of the plant are toxic to stock—both cattle and sheep—and to human beings, and that the presence of the plant constitutes a menace to the pastoral industry.

POSSIBLE USES OF CAPE TULIP

The leaves contain fibre suitable for reinforcing plaster-board, and there have been attempts to utilize this material, due to the shortage of sisal. Gathering and retting are, as yet, in the experimental stage in Australia (Meadley, 1943).

CONTROL AND ERADICATION

(*a*) *Experience in Australia.*—Cashmore (1938), working with pot cultures, found that underground reserves were at their lowest level and leaf-production at a maximum at flowering time, and suggested that weed-killers and cultivation should be applied at that time—*i.e.*, at flowering. He suggested that raising the fertility of the soil, with introduction of suitable pasture plants, was worth considering as a phase of the problem of control of cape tulip.

Davies (1942) reported that the Council of Scientific and Industrial Research after six years of tests with chemical weedicides obtained no satisfactory results with either cape tulip or other perennial weeds.

The Department of Agriculture, New South Wales (1935), suggested several methods of control :—

(i) With scattered plants or small patches, hoe out and burn the corms :

(ii) Use of kikuyu grass for smothering the weed :

(iii) Use of arsenic pentoxide (As_2O_5) at rate of 1½ lb. to 1 gallon water : spraying required to be repeated three or four times—the operations to be carried out about flowering time, and stock to be kept off sprayed area to avoid toxic effects of arsenic compounds.

Clarke (1939) noted that with small patches very heavy applications of highly concentrated weed-killers gave some results. He suggested at least one application of spray (exact type not stated) should be made early in the growing season, soon after the plants have appeared above ground, and he also suggested digging out and burning of small infestations.

For arable land, cultivation is recorded as a means of reducing vigour and intensity of the weed, repeated cultivations being required before placing under crop. It is to be stressed that this method gives no degree of permanent eradication, but only a measure of control.

Meadley (1943) pointed out that any control measures applied against cape tulip must be designed not only to prevent seed-formation, but also to forestall the development of new corms. He found that these begin to develop about August, which observation is supported by Cashmore (1938), who found new corm-formation during August and early September. Since full flowering does not occur until mid-September and seeds are not mature until a month later, the time of corm-formation, rather than that of seed, influences the initiation of control measures. He states that the only satisfactory means of control are grubbing and cultivation, the latter being associated with a cropping programme. Unless the plants are grubbed at the beginning of August or earlier, there is every chance that new-season corms will have been formed and remain in the soil when the plant proper is removed. When the flowering stage is reached the basal corm-development is well advanced, and grubbing at this stage often serves to distribute the weed rather than reduce the infestation.

Repeated mowing to prevent flowering will arrest the spread, although there is no experimental evidence to show whether the density of the infestation is reduced by the operation. Chipping with a hoe will prevent seed-formation, but this, of course, is only a temporary expedient, rather than a means of eradication. "Spectacular results cannot be expected, and any scheme necessitates carrying out systematic measures for a number of years."

(*b*) *Work at Hamilton Bay.*—Control work to the present has consisted of grubbing out isolated plants on the outskirts of the main infested block, and a series of trials with sodium chlorate have been laid down by Mr. G. Shand, Inspector of Stock at Blenheim.

FUTURE OF THE WEED AT HAMILTON BAY

The infestation of one-leaved cape tulip at Hamilton Bay is viewed as a serious one, due to the poisonous nature of the plant, and action should be taken towards control, and ultimate eradication, of the plant. At present it is confined to one property in one locality in this country, and now is the opportune time to prevent further spread. Any further spread of such a poisonous plant constitutes a menace to our pastoral industry, and it must be pointed out that the plant prefers hill country rather than the flats, the specific name, "*collina*," being illustrative of the feature. This means that country where the greatest eradication problems exist is the type of country preferred by this weed.

For isolated plants, grubbing is recommended, and for thick patches of large extent, afforestation appears to be the only reliable method for control.

REFERENCES

(1) BLACK, J. M. (1922): "Flora of South Australia," p. 114.
(2) CARNE, W. M.; GARDNER, C. A.; and BENNETTS, H. W. (1926): "The Poison Plants of Western Australia," revised edition, pp. 68–69.
(3) CASHMORE, A. B. (1938): *J. Council of Sci. and Ind. Res. (Aust.), 11,* 233–238.
(4) CLARKE, G. H. (1939): *Dept. Agr. (South Australia) Bull. 343, Part 2,* 30–42.
(5) CURRIE, G. A. (1936): A Report on a Survey of Weed Problems in Australia, p. 24. *Council of Sci. and Ind. Res. (Australia) Pamphlet No. 60.*
(6) DAVIES, J. G. (1942): *J. Council of Sci. and Ind. Res. (Aust.), 15,* 252.
(7) Department of Agriculture, N.S.W. (1935): "Know Your Weeds," pp. 5, 13.
(8) Department of Agriculture and Intelligence of South Australia (1907): *Bulletin No. 28.* Noxious Weeds, p. 21.
(9) Department of Scientific and Industrial Research (New Zealand), (1944): *18th Annual Report,* p. 25 (records the plant for the first time in New Zealand).
(10) EWART, A. J. (1909): "The Weeds, Poison Plants, and Naturalized Aliens for Victoria," pp. 57–58, 79.
(11) HURST, E. (1942): "The Poison Plants of New South Wales," pp. 68–71.
(12) MEADLEY, G. R. W. (1943): *J. Dept. Agr. (Western Australia), 20,* No. 2, 133–137.
(13) STEYN, D. G. (1934): "The Toxicology of Plants in South Africa," pp. 549–551.
(14) 1893, *10, Victorian Naturalist,* 145. Record of Plants naturalized in the Colony of Victoria since 1889.
(15) WATT, J. M., and BREYER-BRANDWIJK, M. G. (1932): "The Medicinal and Poisonous Plants of South Africa," p. 31.

SOIL DISINFECTION

II. PRELIMINARY REPORT ON CONTROL OF DAMPING-OFF

By H. JACKS, Plant Pathologist, Plant Diseases Division, Plant Research Bureau, Department of Scientific and Industrial Research

[*Received for publication 13th November, 1944*]

Summary

(1) Soil artificially infected with pythium causing damping-off of tomato seedlings, was treated with chloropicrin, formalin, DD, and steam.

(2) Chloropicrin and DD were applied in two different ways—(*a*) injected directly into seed-boxes, and (*b*) injected into soil held in a closed container.

(3) Chloropicrin, formalin, and steam gave complete control of damping-off; the former two caused improved plant-growth; DD gave contradictory results and is under further investigation.

INTRODUCTION

THE control of damping-off (*Pythium ultimum* Trow.) in New Zealand was investigated by Brien and Chamberlain (1936). They concluded that of the chemical treatments tested, formaldehyde solution gave the most effective results. For practical purposes, however, it is desirable that any treatment should also be effective in the control of parasitic soil nematodes. In an earlier report, Jacks (1944), certain chemicals were recorded as showing promise in the control of eelworm, and in the present paper further trials with these materials in control of damping-off fungi of tomato seedlings are reported.

EXPERIMENTAL METHODS

Soil of standard glasshouse mixture, steam sterilized and unsterilized, was inoculated by thoroughly mixing cultures of *P. ultimum* with the soil. After seven to ten days the soil was treated with the test materials, transferred to boxes (18 in. by 12 in. by 3 in.), and fourteen days later planted with five hundred tomato-seeds per box. Treatments were carried out either in triplicate or in quadruplicate, and records were taken four to five weeks later of total emergence, post-emergence infection, growth, height, and weight of plants. The number of seedlings in steam-sterilized soil was taken as a standard, and germination in other treatments was corrected to this standard.

Formalin (40 per cent. solution of formaldehyde) at a dilution of 1–80 was applied at the rate of half a gallon per box—*i.e.*, 28·5 ml. formalin in 2372 ml. water.

Chloropicrin and DD (dichloropropane-dichloropropylene) were applied by two methods. In experiments 1 and 3 the soil was held in sealed containers for forty-eight hours after the chemicals were injected into the soil at half its depth. In experiment 2 the soil was held in wooden boxes, the chemicals injected and after watering the surface with 1 pint of water per box, they were covered with wet sacks. The soil was dug over twice before sowing.

RESULTS

The results of experiments are given in Table I.

TABLE I.—RESULTS OF CHEMICAL TREATMENTS OF SOIL INFECTED WITH DAMPING-OFF FUNGUS

Treatment.	Amount applied for 0·3 Cubic Foot of Soil.	Mean Number of Plants per Box.	Mean Percentage Germination*	Mean Percentage Infection of Emerged Plants.	Average Weight of One Hundred Plants, in Grams.	Average Height of Plants, in Inches.
			Steam-sterilized Soil			
Experiment 1—						
Formalin (1–80)	0·5 gal.	486·0	100·6	0·0	..	..
Steam sterilized	..	484·0	100·0	0·0	..	..
Chloropicrin ..	2 ml.	480·7	99·3	0·0	..	..
Chloropicrin ..	4 ml.	483·0	99·7	0·0	..	..
Check ..	..	315·7	51·3	40·0	..	..
			Steam-sterilized Soil			
Experiment 2—						
Formalin (1–80)	0·5 gal.	461·8	98·8	0·00	23·0	3·18
Steam sterilized	..	469·3	100·0	0·00	17·2	2·44
Chloropicrin ..	2 ml.	467·5	99·7	0·01	18·0	3·21
DD	2 ml.	242·3	51·8	65·90	19·7	2·46
Steam sterilized after inoculation	..	485·3	104·0	0·00	14·3	2·80
Check ..	..	154·8	33·2	57·00	16·8	1·95
			Unsterilized Soil			
Experiment 3—						
Formalin (1–80)	0·5 gal.	472·5	113·0	0·00	44·3	3·97
Steam sterilized	..	417·5	100·0	0·00	31·5	3·43
Chloropicrin ..	2 ml.	482·0	111·0	0·00	48·4	4·38
DD	2 ml.	421·3	101·0	0·01	45·8	4·62
Check ..	..	189·0	45·0	75·30	37·5	2·36

* Percentage germination is based on steam treatment taken as 100 per cent.

All treatments gave effective control of damping-off with the exception of DD used directly into soil in boxes (experiment 2). Chloropicrin and formalin gave improved plant-growth as compared with checks. DD in experiment 2 appeared to retard growth, whereas in experiment 3 it led to increased plant vigour. The growth response in steam-disinfected soil was variable and was probably due to the difficulty of treating accurately small quantities of soil. The drenching of soil with solutions of formalin altered the physical structure of the soil and necessitated frequent tilling, whereas the injection of volatile chemicals did not alter the tilth of the soil.

CONCLUSION

The results here recorded show that chloropicrin and DD are effective in control of damping-off. Since earlier reports indicate their value in control of eelworm it appears probable that these materials will serve the dual purpose of controlling soil fungi and nematodes.

REFERENCES

BRIEN, R. M., and CHAMBERLAIN, E. E. (1936): Tomato Seedling Damping-off. *N.Z. J. Agr.*, *52*, No. 5, 257–267.

JACKS, H. (1944): Soil disinfection: I. Preliminary Report on Control of Eelworm. *N.Z. J. Sci. & Tech.*, *26* (*Sect. A*), 186.

BACTERIAL-SPOT OF PLUM AND PEACH

By W. D. REID, Senior Bacteriologist, Plant Diseases Division, Department of Scientific and Industrial Research

[*Received for publication, 15th January, 1945*]

Summary

Bacterial-spot of plum and peach caused by *Xanthomonas pruni* (Smith) Dowson is prevalent in New Zealand on Japanese plum varieties. The incidence of the disease and morphology and physiological reactions of the causal organism are given. Symptoms of infection consist of leaf-spotting, similar to shot-hole caused by *Phyllosticta prunicola*, small dark-brown circular lesions on fruits, and raised rough elliptical lesions on twigs and branches. Large cankers are formed on branches, and, where present, check the growth of trees. Experiments on control measures have included spraying with Bordeaux, lime-zinc sulphate, and lime sulphur, and top-dressing soil with nitrate of soda. Though spray damage resulted from applications of the two former mixtures, Bordeaux ($1\frac{1}{2}$–3–50) decreased infection from 27·85 per cent. to 7·8 per cent. without serious damage to foliage. Zinc sulphate gave a significant decrease in infection from 27·85 per cent. to 22·37 per cent., but, because of accompanying foliage damage, is of doubtful value for control of bacterial-spot.

IN January, 1929, plum fruits infected with *Xanthomonas pruni* (Smith) Dowson were received from Hamilton district, but it was not until the year 1941 that the disease was found to be widespread in New Zealand. This disease was first reported by E. F. Smith in 1903 from the United States of America, and since has been recorded from Canada, Brazil, Australia, and Japan.

INCIDENCE

Infected fruit and twigs have been received from Auckland, Hawke's Bay, Nelson, Christchurch, and Otago fruitgrowing areas. Specimens have included the plum varieties Alpha, Billington, Burbank, Delaware, Doris, George Wilson, Masterpiece, October Purple, Patterson's Late, Scarlet Delicious, Shropshire Damson, Sultan, and Victoria, and the peach varieties* A1, Alton, Aunt Becky, Edward VII, Elberta, Franklin, Ideal, Kalamazoo, Le Mainqueur, Paragon, Rosebud, Rowe's Champion, Shanghai Slip, and Watton. The disease causes cankers on branches and twigs and lesions on leaves and fruits. Young trees are seriously affected in that early infection produces extensive canker formation on branches and stunting of the trees. Late infection in old trees does not affect branches or main laterals, but, as in young trees, causes cankers on twigs and numerous lesions on leaves and fruits. Spread within a block of trees largely depends on proximity to a source of infection, and chance of transference in picking and pruning. It is not uncommon to find blocks of disease-free trees adjacent to blocks of diseased trees but separated by three or four rows of apple or pear trees. In most infected orchards the disease can be traced to recent replacements with young diseased trees. George Wilson, October Purple, and Sultan varieties appear to be the most seriously affected, but at present not sufficient is known to indicate the relative susceptibility of orchard varieties. In a preliminary inoculation trial of forty varieties of plum, all of which proved susceptible, the English varieties were highly resistant.

* The peach specimens were collected from a small area of close-planted trees in Auckland, but peach infection has not been recorded from commercial orchards or nurseries.

In the United States of America the disease is restricted to the genus *Prunus* and is known to infect Japanese plum, peach, apricot, nectarine, mazzard, Chinese bush cherry, Japanese apricot, almond, and Chinese wild peach. At present it is known only on plum and peach in New Zealand, and whereas it is apparently a serious disease on peach in United States of America it is on plum that the trouble is serious in this country.

SYMPTOMS

Infection occurs on all green parts, including leaves, stems, buds, and fruits.

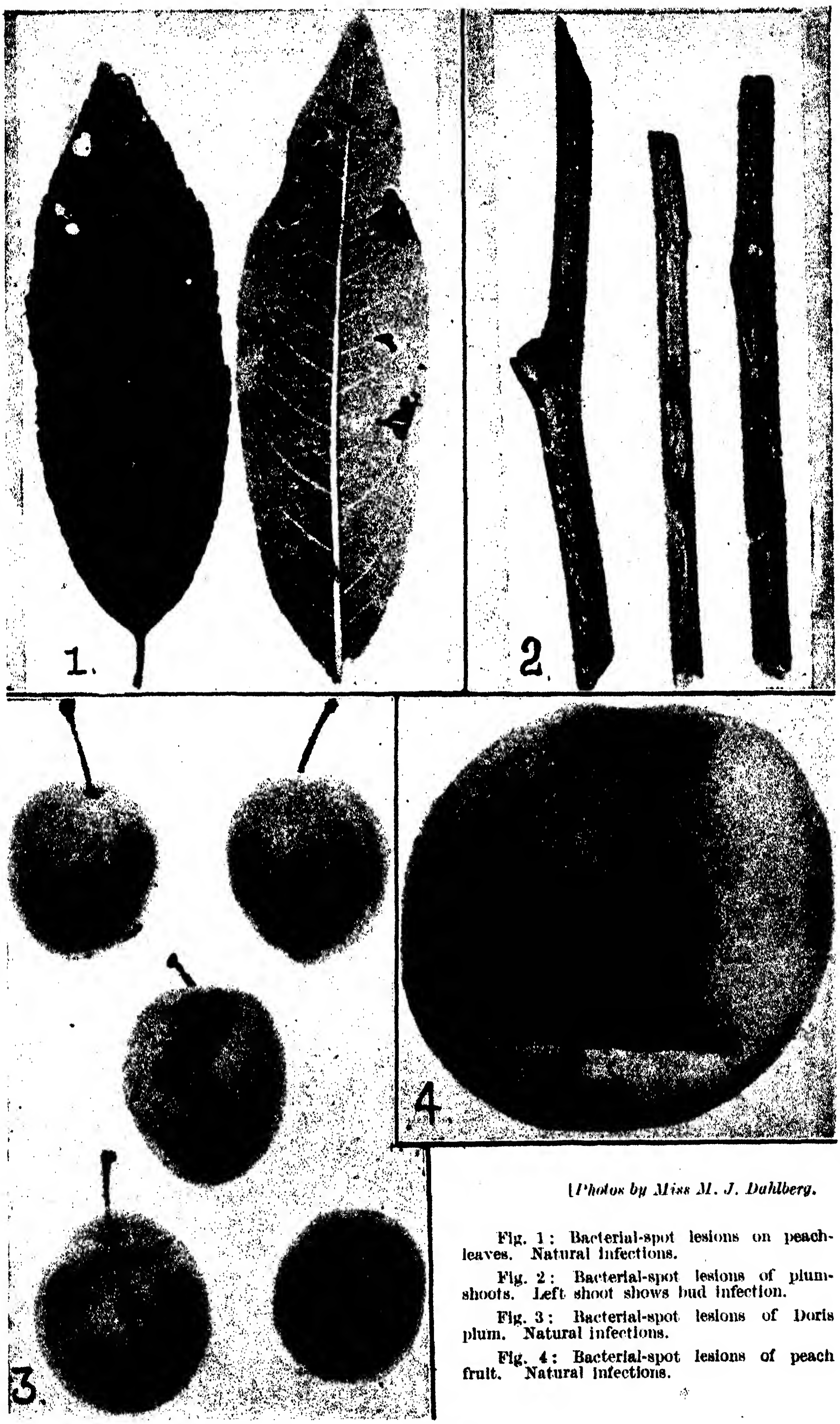
On leaves bacterial-spot of plums is readily confused with shot-hole (*Phyllosticta prunicola*), but can be distinguished by the presence in the former of an oily sheen, particularly on the under-leaf surface. Usually bacterial-spot lesions are smaller and often coalesce to form continuous areas of infection, covering as much as a third of the leaf surface. Like shot-hole caused by *Phyllosticta prunicola*, the bacterial-spot lesions break away from the inner edge of the raised margin and produce numerous leaf perforations. Leaf lesions first appear in early November and attain an average of five to six per leaf in late December. Sixty lesions on a single leaf is not uncommon, but defoliation does not appear to be marked. On peach the leaf lesions are similar in appearance to those on plum, though they have less tendency to break away from surrounding tissue (Fig. 1).

On stems, twigs, and buds areas of infection differ in appearance with age of the lesion. The first symptom on spring growth occurs as a small oily or water-soaked spot. After three weeks the lesion becomes brown to black, oval in outline, and up to half an inch in length. At first the infected surface is smooth, but with increasing age the periphery becomes raised and rough. After three months the outer zones of a lesion are one to three millimetres above the normal level and are traversed by many deep longitudinal crevices from which gum exudation often takes place. Where a number of lesions occur together the shoot is much distorted (Fig. 2). Internally the infected wood is dark brown and extends from 1 mm. to 5 mm. beyond the limit of the superficial lesion. The bark of older branches becomes deeply fissured for many inches in length and tends to lift from the underlying wood. Branches die or become so affected that tree vigour is seriously impaired.

Lesions on fruits first appear towards the end of November, when fruit is half-grown and green. They are small, 1 mm. to 3 mm. in diameter, circular, water-soaked spots with dark-brown pin-head centres. Within a few days lesions darken and finally become dark brown or black. The colour is even, with a narrow light-brown periphery sharply delimited from the green of the fruit. When small, lesions are flat and smooth, but with increasing size up to 12 mm. diameter they become depressed with an abruptly raised border. The surface usually remains smooth, but may be covered by a thin, grey film of dried ooze. Cracking across lesions is common in ripened fruit (Figs. 3 and 4). On peach fruits, lesions are small, 3 mm. to 6 mm. across, brown in colour, and raised as irregular pustules in contrast with the large smooth depressed lesions on plum.

ISOLATION OF CAUSAL ORGANISM

The causal organism is readily grown on laboratory media when isolated from young lesions on leaves, shoots, and fruits. Isolation is difficult from partly broken shot-hole of leaves, from shoots more than one year old, and from large lesions on mature fruit.



[*Photos by Miss M. J. Dahlberg.*

Fig. 1: Bacterial-spot lesions on peach-leaves. Natural infections.

Fig. 2: Bacterial-spot lesions of plum-shoots. Left shoot shows bud infection.

Fig. 3: Bacterial-spot lesions of Doris plum. Natural infections.

Fig. 4: Bacterial-spot lesions of peach fruit. Natural infections.

FIGS. 1–4.

To test pathogenicity, many single-colony isolations from different types of lesions were used for needle inoculation of plum and cherry plants grown in a glasshouse. Lesions were formed in six days, and, though subsequent development was slow, symptoms were typical of natural infections. Identification of the organism was made by the morphological and physiological reactions suggested by the Society of American Bacteriologists.

MORPHOLOGY

The organism exists as short rods with rounded ends, singly and pairs, 0·4–1·8 μ by 0·3–0·45 μ, with an average of 1·0 μ by 0·4 μ for single rods, 0·8–3·6 μ by 0·3–0·45 μ for pairs, and 7·0–20·0 μ for chains. It is motile with one to three polar flagella (Fisher and Conn, 1942), and is gram negative. Capsules are present.

CULTURAL CHARACTERISTICS

Cultures, except those on gelatine, were held at 27° C. *Beef-peptone-agar* colonies: Growth moderate, colonies in two days punctiform, smooth, entire, convex, translucent, viscid. *Beef-peptone-agar* slant: Growth moderate, convex in three days, raised in six days, smooth, shining, entire, yellow, dry, no odour. *Potato slice:* 3 mm. width in three days, filiform, convex, smooth, dull, entire, cadmium yellow, potato grey: in 12 days 3–4 mm., tan, potato dark brown at top. *Nutrient-gelatine* plate: Cadmium yellow growth with immediate liquefaction. *Nutrient-gelatine* stab: Growth rapid on surface, 3 mm. depression in two days, crateriform liquefaction in three days: stratiform, 15 mm. deep, in 12 days, yellow to orange sediment. *Plain-gelatine:* As for nutrient-gelatine, but less active. *Nutrient-broth:* Faint clouding in two days, white ring in three days, coarse pellicle, grey viscid sediment in six days, no odour. *Litmus milk:* No change in three days: in six days 6 mm. clear whey, remainder yellow-pink; in nine days 6 mm. whey, remainder yellow-orange, granular sediment, not viscid, no coagulation; in 12 days peptonized, ochre yellow base, sediment viscid. *Nitrites* not formed, but *ammonia* formed. *Hydrogen sulphide:* Slight production in seven days using sodium thiosulphate medium and lead acetate strip test. *Starch:* Doubtful hydrolysis. *Indole* not produced using Gore test with tryptophane. *V.P. test:* Positive. *M.R. test:* Positive. *Carbohydrate Media:* No gas formed; in ammonium phosphate medium slight acid produced in four days in arabinose, glucose, fructose and sucrose; no change or slight alkalinity in galactose, maltose, raffinose, starch, dextrin, glycerol, salicin, mannitol, lactose, inulin. *B.P.A. plus carbohydrates:* Slight acid in six days in all above except maltose, raffinose, mannitol and slight alkalinity in arabinose, with change to slight alkalinity in all except glycerol in twenty-one days.

Morphologically it is similar in size, presence of capsule, and flagella to previous descriptions of *B. pruni*. Dunegan (1932) reported only one polar flagellum, which is contrary to results of E. F. Smith and F. M. Rolfs, who found from one to several. The organism is difficult to stain, but a number of rods with three polar flagella have been observed. A small amount of hydrogen sulphide is formed which is not in agreement with result of Dunegan, but the basal medium was not the same, and Dunegan restricted the test to eighteen hours. Bergey stated that *B. pruni* precipitates casein, but this is a misquotation of Dunegan. The reaction in beef-peptone-agar plus carbohydrates is similar to that of Dunegan, but in ammonium phosphate medium Dunegan observed acid production in all carbohydrates tested.

The above differences are slight or could be caused by variations in technique, and are not sufficiently marked to suggest that the New Zealand organism is other than *B. pruni*. Recently Dowson (1939) reclassified *Bacterium pruni* Smith as *Xanthomonas pruni* (Smith) Dowson.

CONTROL MEASURES

The presence of lesions on fruits causes extensive losses of marketable fruit. Experiments have been carried out to determine some method of

reducing this annual loss. Treatment of plum-trees for control of disease is unusual in New Zealand, and there is no evidence, based on practical experience, to suggest a control method. In North America the use of sprays and the use of nitrogenous fertilizers have been recommended. According to Manns and Adams (1934; 1935), zinc-sulphate spray appreciably reduces fruit infection, though Kadow and Anderson (1935) and Hurt (1937) obtained poor results with this spray material. Poole (1940) applied periodical soil dressings of nitrate of soda and stated that trees " were slightly infected only." Apparently neither method in America gives a complete control, but, in view of the serious loss in New Zealand, experiments were carried out to determine the value of these treatments.

In June, 1942, a block of thirty-seven George Wilson and sixty Doris plum-trees seven to eight years old was selected for treatment. The George Wilson trees were small, rarely more than 7 ft. in height, and severely cankered on main branches and twigs. The Doris trees were between 11 ft. and 17 ft. in height and infected only on the smaller branches and the twigs. The block consisted of alternate pairs of rows of the two varieties, and eight replications of treatments and four of untreated trees were arranged in random form. Each plot included both varieties.

For the 1942–43 season the treatments were as follows:—

(1) Winter pruning to remove infected twigs.

(2) *Spray Treatments.*—(*a*) Bordeaux 4–4–50 (4 lb. copper sulphate, 4 lb. hydrated lime, 50 gallons water) applied to the majority of trees in the dormant period. (*b*) Bordeaux 4–4–50, followed by four applications of lime 4–50 (4 lb. hydrated lime to 50 gallons water), zinc sulphate-lime 4–4–50 (4 lb. zinc sulphate, 4 lb. hydrated lime, and 50 gallons of water), or lime-sulphur 1–120 (1 gallon lime-sulphur of 15 per cent. polysulphide content to 120 gallons water). (*c*) Non-sprayed check trees. The three last applications included 4 oz. of a wetting agent, Agral 2, in each 100 gallons of spray.

In view of the apparent improvement in above experiment with Bordeaux and the reported value of soil dressings with nitrate of soda the 1943–44 experiments were modified to include these treatments. The lime spray was replaced by nitrate of soda, and trees previously used for the dormant spray of Bordeaux were treated with the full number of Bordeaux applications. The treatments therefore were as follows: (*a*) Bordeaux, 3–4–50 for first two sprays and 1½–3–50 for subsequent applications; (*b*) zinc sulphate-lime, 2½–4–50; (*c*) lime-sulphur, 1–120; (*d*) nitrate of soda, 1 lb. for each Doris tree and ½ lb. for each George Wilson tree applied under trees in eight dressings at ten-day intervals commencing 2nd July, 1943; (*e*) untreated check trees.

Trees other than check trees were sprayed with Bordeaux 3–4–50 during dormancy on 2nd July, 1943. The additional treatments were applied on 2nd August, 14th September, 15th October, 3rd and 19th November, 6th and 22nd December, 1943. A wetting agent, Agral 2, at 4 oz. to 100 gallons was included in all Bordeaux applications except the first on 2nd August, 1943.

In the winter pruning all George Wilson trees and half the Doris trees were severely pruned by cutting out infected twigs or small branches (Fig. 5), trees being reduced to a framework of main branches. The remainder of the Doris trees were lightly pruned by removing diseased twigs of the previous season's growth.

As a guide for future experiments counts were made of lesions on leaves, fruits, and new twig growth. Approximately forty leaves from two zones between ground and 7 ft. high were selected at random from each tree, and all lesions recorded. Two counts of leaves, three of fruit and three of twigs, were made during each season.

RESULTS

Incidence of Disease.—The development of lesions during 1942–43 season is shown in Table I.

TABLE I.—OCCURRENCE OF BACTERIAL-SPOT ON DORIS PLUM-TREES DURING 1942–43 SEASON

Date recorded.	29/9/42.	19/11/42.	30/11/42.	23/12/42.	25/2/43.	23/6/43.
Leaves ..	First infection	..	..	..	..	..
Lesions on forty leaves	..	..	32·6	153	..	..
Fruits ..	..	First infection	..	..	..	..
Percentage infected	..	..	11	26·4	36·5	..
Shoots ..	..	First infection	..	..	..	..
Percentage infected	..	..	5·1	25·0	..	79·8

During the 1943–44 season the occurrence of lesions corresponded closely with that of the previous season. Leaf, twig, and fruit infections were first observed on 7th October, 19th November, and 3rd December respectively. By 22nd December fruit infection was general, with an average of 11·6 per cent. of fruit infected. Evidently development was later than in the previous season, and the final amount of fruit infection as shown in Table III was less.

Effects of Treatments.—In Table II are given the effects of treatments in the 1942–43 season on infection of leaves, fruit, and shoots of Doris and George Wilson trees.

TABLE II.—EFFECTS OF SPRAY MATERIALS ON INFECTION BY BACTERIAL-SPOT OF PLUMS

——	Leaves: Lesions on Forty Leaves.		Fruits: Percentage Infected.		Shoots: Percentage Infected.	
Date recorded	30/11/42 to 2/12/42.		25/1/43 to 1/2/43.		22/6/43 to 1/7/43.	
Variety	Doris.	G. Wilson.	Doris.	G. Wilson.	Doris.	G. Wilson.
Treatment						
No treatment	41	32	34·1	33·3	80·8	59
Lime	40	23·4	41·1	42·0	81·1	54·5
Lime and zinc sulphate ..	26	15	42·5	43·0	77·3	55·7
Lime-sulphur	23	27·7	31·9	34·0	81·0	50·0
Dormant Bordeaux ..	27	27·6	33·3	23·1	69·0	46·2

The zinc-sulphate spray caused extensive damage and dropping of foliage. The differences are not significant, but the low infection of shoots and fruit following the single Bordeaux spray suggested the further trial of this material in the following season.

In the 1943–44 season the two early applications of 3–4–50 Bordeaux caused leaf and twig damage, and for later applications the concentration was reduced to 1½–3–50. Effects of the treatments on fruit infection at time of picking, 26th January to 16th February, 1944, are given in Table III.

TABLE III.—EFFECTS OF SPRAY TREATMENTS ON OCCURRENCE OF FRUIT LESIONS OF BACTERIAL-SPOT

—	Bordeaux.	Zinc Sulphate.	Lime-sulphur.	Nitrate of Soda.	Check.	Mean.	Difference required for Significance at 5 per Cent. Level.
Mean percentage infection	7·8	22·37	24·57	26·87	27·85	21·9	5·36

FIG. 5.—Doris tree severely pruned during winter of 1943.

From the table it is obvious that Bordeaux spray gave a highly significant reduction in disease. The difference shown by zinc sulphate is also significant, but the amount of spray damage associated with this spray material outweighs its value as a bactericide.

Leaf and twig infection varied with treatment, but differences were not as marked as those obtained with the fruit. Final twig counts were made during pruning, 26th June, 1944, six months after the last spray application. They showed the following proportion of infected twigs: Bordeaux, 33·0 per cent.; zinc sulphate, 77·5 per cent.; lime-sulphur, 73·0 per cent.; nitrate of soda, 72·1 per cent.; checks, 83·0 per cent.

In the 1943–44 season there was a general increase in fruit-production above that of the previous season. In Table IV are given percentage increases associated with the various treatments.

TABLE IV.—EFFECT OF TREATMENTS ON INCREASED FRUIT-PRODUCTION OF 1944 SEASON OVER 1943 SEASON

—	Bordeaux.	Zinc Sulphate.	Lime-sulphur.	Nitrate of Soda.	Check.	Mean.	Difference required fo Significance at 5 per Cent. Level.
Mean percentage increase	386	306	308	861	559	484	467

From the above table it is evident that no treatment gave an increase significantly different from the checks, though the nitrogen treatment is significantly greater than the three spray treatments. In the latter case the difference arises from a combination of the increase caused by nitrate of soda and a decrease caused by spray treatment.

DISCUSSION

Results of treatments show that infection by bacterial-spot can be reduced by applying Bordeaux or zinc-sulphate sprays, but because of spray damage the reduction arising from use of the latter is not sufficient for practical purposes. Bordeaux 3–4–50 also causes foliage damage, but the high degree of control of bacterial blight with 1½–3–50 justifies further experiments to determine the optimum concentration of this spray material and the minimum number of applications required. H. B. S. Montgomery, M. H. Moore, and T. N. Hoblyn, at East Malling, have also reported foliage damage of plum with 6–9–100 Bordeaux and good control of bacterial canker (*Pseudomonas morsprunorum*) without damage with Bordeaux 4–6–100. In the preceding experiments only Doris and George Wilson varieties were used, but preliminary trials show that other Japanese varieties are also susceptible to foliage injury by copper sprays.

Soil dressings with nitrate of soda did not reduce the incidence of bacterial-spot. Severe winter pruning, instead of reducing the amount, increased infection of both fruit and shoots.

Much of the shoot infection (see Table I) occurs in late summer and autumn, and it is possible that summer pruning of infected twigs or additional Bordeaux sprays in the autumn would afford some protection for new growth during the autumn period.

REFERENCES

DOWSON, W. J. (1939): On the Systematic Position and Generic Names of the Gram Negative Bacterial Plant Pathogens. *Zbl. Bakt., Vol. 100, No. 9/13*, pp. 177–193. 1939.

DUNEGAN, J. C. (1932): The Bacterial-spot Disease of the Peach and other Stone Fruits. *United States Dept. of Agr. Bull. 273.*

FISHER, P. J., and CONN, JEAN E. (1942): A Flagella Staining Technic for Soil Bacteria. *Stain Techn., 17*, 117–21.

HURT, R. H. (1937): The Control of Peach Leaf-curl, Scab, and Brown-rot: (2) Spray Materials for Peaches. *Bull. Va. Truck Exptl. Sta. 312. Abst. R.A.M., Vol. 17*, pp. 255–6. 1938.

KADOW, K. J., and ANDERSON, H. W. (1935): The Role of Zinc Sulphate in Peach Sprays. *Bull. Ill. Agr. Exptl. Sta. 414. Abst. R.A.M., Vol. 15*, p. 235. 1936.

MANNS, T. F., and ADAMS, J. F. (1934): *Ann. Rept. Delaware Agr. Exptl. Stat. Bull. 188*, pp. 36–46. *Abst. R.A.M., Vol. 13*, p. 563–4.

——— (1935): *Rept. Del. Agr. Exptl. Sta. Bull. 192*, pp. 40–49. *Abst. R.A.M., Vol. 14*, pp. 682–3.

MONTGOMERY, H. B. S.; MOORE, M. H.; and HOBLYN, T. N. (1943): A Field Trial of Measures designed for the Control of Bacterial Canker of Victoria Plum-trees. *Ann. Rept. E. Malling Res. Sta.* pp. 53–61, 1942.

POOLE, R. F. (1940): The Relation of Nitrogen Fertilization of the Peach to the Control of *Bacterium pruni.* Abst. in *Phytopathology 30*, p. 706. 1940.

ROOT DEVELOPMENT IN SOME COMMON NEW ZEALAND PASTURE PLANTS

IV. A METHOD OF ROOT SEPARATION

By W. A. JACQUES, Massey Agricultural College, New Zealand

[*Received for publication, 18th December, 1944*]

Summary

A method of obtaining root-weights from pasture swards, and the technique employed in separating them from soil and organic matter, are discussed. The method outlined is suited to soils free from stones and excessive amounts of organic matter.

INTRODUCTION

MANY different methods have been devised for the analysis of the root population in the soil, each one to suit special circumstances. The governing factors in determining the method that shall be employed are species, soil type, climate, water-supply, proximity of the area to the laboratory, type of information it is desired to obtain, and the personnel available to do the work. Where the personnel is adequate there is little difficulty in sampling at the correct time, but where it is small, factors arise which delay sampling which can modify results considerably. If, for example, a large block of soil is examined for roots from each of a number of different treatments, there follows a lack of sample distribution. In addition, there is an inevitable interval of time between the preparation and examination of one sample and the next, and a greater one between different series. During these time-intervals, changes may be taking place in the root system. The changes may be considerable in the period of greatest root activity where there is a great increase in root-weight and often depth of penetration, whilst in the period when dry weather is setting in and the plants are approaching their culminating point of growth for the season (November–January) there could be a rapid loss in the root-weight of grasses.

If, on the other hand, a number of small samples is taken simultaneously from any one treatment and the sampling is rotated around the different treatments, randomization is obtained, but there follows an inevitable time-lag between sampling the first and the last treatments of the series. This, however, appears to be the more satisfactory method. The sampling method that has been adopted with some root-development investigations at this centre, where lack of personnel has made some sampling compromise necessary, has been to take single small prisms of soil 12 in. long (using a root sampler designed for the purpose(1)) from each of the different treatments of a series on a given sampling date. The most ambitious trial attempted by this method was one to determine root-weight and root-penetration in the different layers of the top foot of soil. For this, five species series were used, each of which was subjected to a no-fertilizer and three different fertilizer placements. Samples were taken to embrace the fertilizer treatments for one species series each week, so that an interval of five weeks intervened between successive samplings of any one species

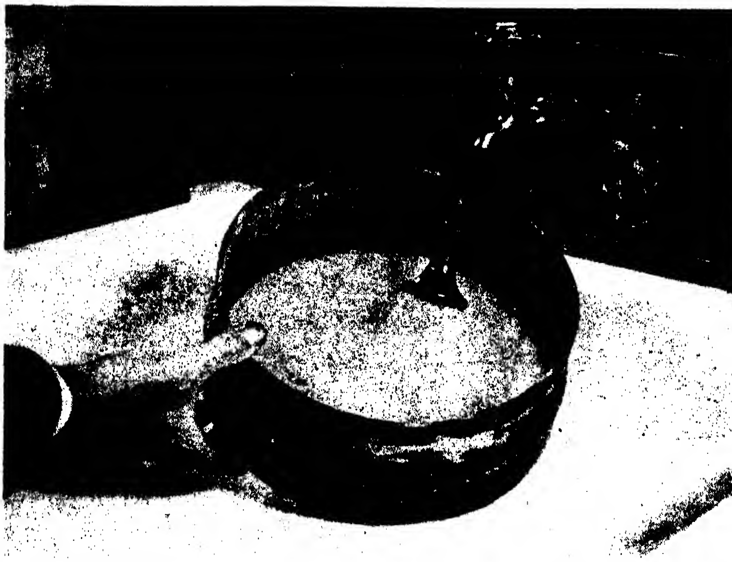
series. The trials were repeated for four successive years with a modification in the method of raising the plants, but not in fertilizer application in each year. Despite the disturbing effect of time between sampling and the small number of samples at each sampling date, major trends could be worked out for each species series over a number of years. With a less ambitious project to cover one or two species only, statistical analysis of results would be possible.

METHOD OF ROOT SEPARATION AND WASHING

The soil prisms $2\frac{3}{16}$ in. by $2\frac{3}{16}$ in. by 12 in. were raised from the plots, taken to the laboratory in special boxes(1), and were cut into sections of the desired thickness. In a suitable pasture soil it was found possible to sample every inch of the profile in this way. If the soil was too dry to cut cleanly, it was moistened by covering it for some hours, or overnight, with a wet cloth. Each section of the prism was washed separately in a horse-hair sieve, the roots collected, dried, and weighed. For some trials the surface layer of the sample can profitably be discarded without unduly affecting the results, for it is the separation of roots from this region that demands a considerable amount of time and especial care. The high organic-matter content at the surface of a pasture soil makes root-separation by any method difficult, but given the time this is a convenient technique. The general method of root-separation used over a period of years for obtaining root weights in a number of experiments was as follows:—

A soil section was soaked by placing it in the sieve and immersing it in a bucket of water until the water was above the level of the soil, but did not reach above the top rim of the sieve frame. The sieve consisted of a circular wooden frame across which was stretched a plain-weave horse-hair mesh. The warp and weft were each made up of four strands of horse-hair and there were seventeen of each to the inch. As they occupied about half of the face, the spaces between each warp and each weft was approximately $\frac{1}{34}$ in. When the soil was softened, a fine spray of water from a rose was directed on to it (Fig. 1), and the soil particles were carried through the holes in the sieve and left the roots, weed-seeds, undecayed organic matter, small stones, and even coarse sand particles on the sieve. Although the holes in the sieve were small enough to prevent the direct passage of unbranched main crown roots through the sieve, the diameter was much greater than that of the finest roots. It was found, however, that if normal care was taken in the separation, the loss of roots was very small. The nature of the surface of the roots, quite apart from any branching, caused their retention on the sieve. The roughness of the horse-hair due to scales, together with the coating of root hairs on the roots, formed a mechanical obstruction to their easy passage through the holes in the sieve. By altering the direction of the spray of water from the rose, the roots were gathered together in a bunch along with any foreign matter that failed to pass through, and they were then ready for transference from the sieve to a glazed earthenware basin or bowl. The transference was performed by inverting the sieve over the bowl and washing the bunch of roots into it (Fig. 2).

In the bowl the roots and other material commenced to settle out at different rates. The heavy material and soil collected quickly at the bottom; many seeds and some foreign organic matter were found to float on the surface or cling to the sides of the earthenware container. If roots floated on the surface (and frequently new roots that were separated from the plant and from older portions of the root did float), then they were collected with forceps before the next operation, otherwise they might easily float away.

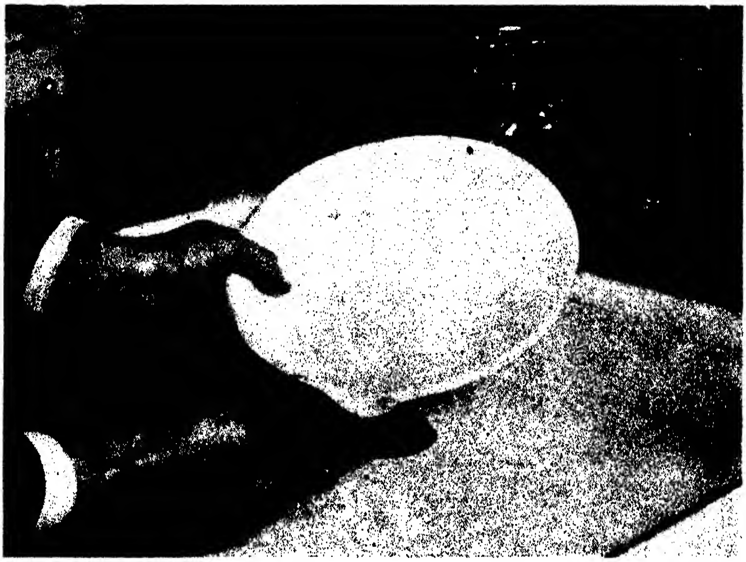


[Photo by Harvey Drake

FIG. 1.—Method of separating soil from roots using a horse-hair sieve and a spray of water.

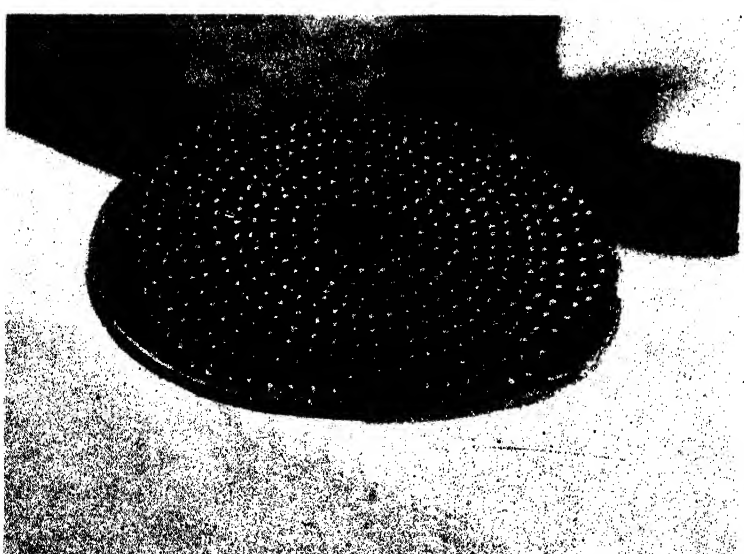
[Photo by Harvey Drake

FIG. 2.—Transferring the separated roots to the earthenware bowl.



[*Photo by Harvey Drake*

FIG. 3.—Collecting the roots by means of a rubber baffle.



[*Photo by Harvey Drake*

FIG. 4.—The rubber baffle.

If there were no floating roots, then the floating seeds could easily be decanted off, but it was always found safer to pass any liquid that was poured from the earthenware container over a red rubber " baffle " (Fig. 3). This baffle (Fig. 4), (which originated as a toilet article) consisted of a flat rubber base from which erect cones of rubber projected. These cones prevented the passage of the roots when liquid from the earthenware basin was poured slowly over the baffle, but permitted round seeds, small short pieces of organic matter, and anything that did not naturally cling to the rubber to be floated off while the roots were retained. By so arranging the separation over the baffle it was possible to separate floating material other than roots from the rather heavier roots, and also the roots from the material that settled rapidly to the bottom, as this could be left in the earthenware container after pouring off all the roots. The material collected on the baffle needed further separation with the forceps. This was done either in water or on glass. If in water, the material from the baffle was washed into a petri dish and examined on a black background, and anything other than roots removed. To collect the roots again the contents of the dish were poured slowly over the baffle, the baffle cleaned on glass, and the roots were then separate from any foreign matter and ready to be dried and weighed. If using plate glass for separating the roots from foreign matter, the baffle was cleaned by striking it sharply several times on the glass. The roots were by this means forced on to the glass; any that did remain on the baffle were easily seen against the red rubber and were picked off with forceps. The roots were collected from the plate glass with a safety-razor blade and were then ready for transference to folded blotting-paper containers to be dried and weighed.

WEIGHING THE ROOTS

It was found that air-dried roots varied considerably in weight with varying temperature and humidity, differences of up to 5 per cent. have been obtained(2). It was therefore desirable to standardize the method of weighing. The technique first adopted (1937 and 1938) was to dry the roots for several days at room temperature and then to transfer them to a constant humidity room where the temperature was maintained at 68° F. and the relative humidity at 60 to 65 per cent. The temperature was maintained very accurately by a thermostat, and the humidity was controlled by a fan directed on to large shallow dishes of salt solution. Violent external humidity fluctuations were reflected to a small extent in the room due to the inadequacy of the brine solution as a means of control. To obviate this error, weighing was done when the humidity had remained constant for about twenty-four hours. A Bunge balance was used, taken as weighing correct to 0·3 milligrams.

The method of drying the roots in 1939 and subsequently was modified. The roots were placed in a vacuum oven and dried at 70° C. After drying they were kept in a desiccator until they were weighed on the Bunge balance.

REFERENCES

(1) JACQUES, W. A. (1937): *N.Z. J. Sci. & Tech.*, *XIX*, *4*, 267–70.
(2) HOPEWELL, H. G. (1939): Unpublished results.

INVESTIGATIONS OF METHODS OF PRESERVATION OF GRASS

By F. D. COLLINS and F. B. SHORLAND, Chemical Laboratory, Animal Research Division, Department of Agriculture, Wellington

[*Received for publication, 30th October, 1944*]

Summary

Methods of preservation of rye-grass (*Lolium perenne*) using boiling alcohol, boiling water, freezing at $-9°$ and $-22°$ C., air drying at 35°, 70°, 105°, and 120° C., and bottling were tested. Vitamin C, phosphatides, free fatty acids, and sugars were used as criteria. As a means of arresting enzymatic or other changes, boiling alcohol or rapid air drying appeared to be equally satisfactory. For subsequent storage of the materials alcohol was more satisfactory unless the dried material was kept out of contact with moisture and air. The free fatty acid and phosphatide contents of grass samples dried at a temperature between 35° and 105° C. were respectively greater than and less than those found for alcohol preserved grass. Grass dried rapidly in a commercial drier at 120° C., however, contained less free fatty acid and free sugar, but the same proportions of phosphatide as grass preserved in boiling alcohol. The free sugar content of the grass dried at 120° C., although initially lower than that of the alcohol preserved material, in the course of thirty-two days increased to approximately six times the original value.

INTRODUCTION

IN the course of investigations in connection with facial eczema the necessity for transporting samples of pasture long distances before extraction has made it important that the methods of preserving grass should be studied. Possible causes of changes in the chemical composition of pasture during storage are enzyme and bacterial activity, oxidation, and loss of volatile constituents.

Drying of grass as a means of preservation has been discussed by Woodman(1). A band drier operating with furnace gases at 200° C. gave a product displaying no significant loss of carotene and digestibility of protein as compared with the fresh grass from which it was made. It has been found that the material being dried should be removed from contact with the hot gases as soon as it is dry.

Bartlett *et al.*(2) studied five methods of drying grass. Drying with a current of air at 57°, 77°, and 150° C. respectively gave similar values for carotene and for the biological values of the protein which were superior to those obtained for grass left to dry in air, exposed to sun or protected from sun and rain. The drying of farm crops has been discussed by Cashmore(3).

Most of the literature on drying as a means of preservation refers to vegetables, which prior to drying are generally blanched. In this process the material is sterilized, but not cooked, by use of boiling water or live steam. This ensures also more effective preservation of vitamin C(4), which is lost in varying amounts(5) according to the type of vegetable. Such losses have been attributed to non-enzymatic catalysis and destruction of protective reducing substances(6). In the case of preservation of other constituents blanching is not necessarily the best practice, and some workers

prefer to dry without blanching(7, 8). The dehydration of fruits and vegetables is discussed by Tressler(9). Davis, Eidt, McArthur, and Strachan(10) stress the need for rapid drying and the importance of low temperature for subsequent storage.

Aykroyd(11) has shown that commercially dried vegetables retain the ascorbic acid content better in sealed tins which prevent the absorption of moisture.

Martson, Quinlan-Watson, and Dewey(12) on the dehydration of lucerne have shown that the leaf-meal prepared by dehydration at 105° to 110° C. with a stream of air contained 80 per cent. of the ascorbic acid originally present in the fresh leaves. The carotene was retained practically quantitatively under these conditions. The rate of destruction of ascorbic acid was greatest during the time when the temperature of the leaves was rising from 50° to 65° C.

When the moisture content was below 4 per cent. the loss of ascorbic acid on storage in vacuo at 37° C. for 210 days was 8 per cent., but in the case of samples exposed to air the loss was over 50 per cent. In samples containing 10 to 11 per cent. moisture, whether stored in vacuo or in air, the loss of ascorbic after 210 days was 85 to 90 per cent. The experiments also confirmed the experience of other workers that the materials immediately after dehydration should be removed from the drier.

In the case of storage of vegetables by freezing, blanching is the usual practice(4, 13). During this process some vitamin C is lost(13), but, provided the temperature is rapidly reduced to below —18° C.(14, 15, 16, 17, 18), the subsequent loss is small.

In the canning practice(19) the raw food is thoroughly cleansed and then blanched in boiling water or with live steam. The food is next put in the can, which is sealed immediately, the dissolved gases having been removed as far as possible by preheating. The can is then heated sufficiently to destroy those bacterial spores that are likely to be present. The optimum temperature for acid foods (less than pH 4·5) is about 93° C. Non-acid foods require a temperature of about 116° C. The tin is then cooled as rapidly as possible to prevent undue softening. The details differ somewhat according to the material being canned. According to Kroker(17) and Dunker and Fellers(20), 25 to 40 per cent. of the vitamin C is preserved during the canning process. The destruction of vitamin C is catalysed by copper and iron, but modern cans are made with very pure tin and there is no loss due to this cause(16).

According to Loomis and Schull(21), boiling alcohol penetrates the tissues rapidly and results in prompt destruction of enzymes. The necessity for rapid destruction of enzymes by boiling alcohol in preparing samples for carbohydrate analysis is also stressed by Davis, Daish, and Sawyer(22). Cold alcohol is much less effective than boiling alcohol. For example, celery-leaves dropped into cold alcohol and quickly brought to the boil contained twice as much reducing sugar as leaves from the same sample dropped immediately into boiling alcohol(21). Cold alcohol, however, is stated by Briese and Couch(23) to arrest enzymic hydrolyses of cyanogenetic glucosides.

In this work phosphatides, free fatty acids, and in some cases ascorbic acid and sugar have been used as criteria to determine the efficiency of preservation. In earlier work low phosphatide values were obtained for grasses ; 0·1 to 0·5 per cent. of the dry matter(24, 25). The effect of treatment

on the phosphatide content of plants does not appear to have been previously studied(26). Recent work by one of us, however, has shown that fresh grass plunged into boiling alcohol contains up to 1·7 per cent. of this constituent(26). This suggested that the phosphatides should prove useful as a measure of preservation.

EXPERIMENTAL

Methods of Analysis

(*a*) *Total Lipid, Phosphatide*, and *Free Fatty Acid*.—In the case of large samples, the fresh or preserved grass was boiled in alcohol and pressed. Small grass samples, after boiling with alcohol, were put through a Health Mine juice-extractor. The fibre was dried, ground, and then extracted with petroleum ether and, finally, with alcohol. The alcoholic pressings were concentrated and extracted with petroleum ether. The combined petroleum ether extracts were washed with water and treated with anhydrous sodium sulphate to remove chlorophyll as described previously(25). To determine the acetone-insoluble material the lipid was boiled with ten volumes of acetone cooled to 0° C. and filtered, the process being repeated until no cold acetone soluble material was extracted. The phosphatides were obtained by boiling the cold acetone insoluble material with ten volumes of acetone and filtering or decanting, while hot, repeating the process until free from waxes. The free fatty acids were estimated as oleic acid by titrating 0·5 g. to 1·0 g. of the cold-acetone-soluble fraction with N/2 alcoholic potash using phenolphthalein as indicator. The neutral alcohol was heated to dissolve the free fatty acid and then cooled prior to titration.

(*b*) *Sugar*.—An aliquot of the water soluble extract of the grass was clarified using the method of Doak(27), modified as follows: to 10 ml. of aqueous extract were added 2 ml. of a 2·26 per cent. solution of cadmium sulphate and 0·3 ml. of 0·55 N sodium hydroxide. After heating to boiling, the solution was allowed to cool and then filtered. The reducing sugar was estimated according to the method of Schaffer and Somogyi(28). For the determination of the total sugars, the solution was hydrolyzed by boiling with 0·05 N sulphuric acid for one hour; then neutralized with N/2 sodium hydroxide and the sugar estimated on the hydrolyzed solution.

(*c*) *Ascorbic Acid* (Vitamin C).—Titration with 2·6-dichlorophenol-indophenol, was used(29, 30). Dehydroascorbic acid was determined after reduction with hydrogen sulphide, removing excess with a stream of carbon dioxide and proceeding as for ascorbic acid.

Methods of Preservation

(*a*) *Boiling Alcohol*.—The freshly cut pasture was dropped into sufficient boiling alcohol to cover the sample and the boiling continued for twenty minutes. For storage purposes the alcoholic solution and the pasture were transferred to airtight jars.

(*b*) *Boiling Water*.—The treatment was the same as described for alcohol, variations in temperature being obtained by the use of an autoclave.

(*c*) *Bottling*.—Two samples of grass were plunged into boiling water and the boiling continued for twenty minutes in a preserving jar at 100° and 120° C. respectively. While still hot, the jars were sealed. On the following day they were retorted, using the same conditions as in the original treatment with the lids loosened, and then again sealed for storage.

(*d*) *Drying.*—In the air-dryer used the grass was exposed to a current of air at 35° or 70° C., using thin layers of grass supported in trays. An oven was used for the sample dried at 105° C.

The grass from Wairoa and Ruakura was dried in a commercial drier using air heated to approximately 120° and under the best conditions taking twenty minutes to dry.

(*e*) *Freezing.*—Small samples (cf Table 1A) were introduced into the inner chamber of a refrigerator for −9° C. For −22° C. the grass was introduced inside a test tube into an alcohol bath supplied with suitable refrigeration.

Materials used for Investigation

For this purpose a plot was prepared adjacent to the laboratory and sown with Perennial rye-grass (*Lolium perenne*) seed. The plot was divided into sixteen strips and sampled at intervals. Each sample comprised four strips selected at random, the grass not having been cut previously.

The larger samples were collected from various localities comprising, in the case of Palmerston North samples, pure species. The other samples were from normally grazed pastures.

RESULTS

TABLE 1A.—THE EFFECT OF TREATMENT ON THE CONTENT OF CERTAIN CONSTITUENTS OF GRASS

(Free Fatty Acid and Phosphatides expressed as Percentage of Dry Material)

Date collected.	Description of Grass. (All samples treated while fresh.)	Treatment.	Wet Weight of Samples (Grams).	Phosphatides.	Free Fatty Acids.
3/9/40	Five months after sowing, Ruakura	Frozen in ice-chest	16,780	0·09	1·63
		Dried at 35° C.	6,410	0·48	0·93
2/5/41	10 in. to 12 in. high, Palmerston North	Boiling alcohol	8,546	1·36	0·54
		Dried at 70° C.	4,464	0·35	1.85
7/10/41	Twelve months after sowing, local plot	Boiling alcohol	454	0·89	0·43
		Frozen at −9° C. for fourteen days	454	0·60	0·35
28/12/41	One month after sowing (6 in. high), local plot	Boiling alcohol	200	0·63	0·32
		Boiling water	100	0·67	0·81
26/1/42	Two months after sowing (7 in. high), local plot	Boiling alcohol	250	2·20	0·32
		Boiling water	454	1·57	0·68
		Dried at 105° C. for twenty-four hours	300	1·23	0·90
		Frozen at −9° C. for ten days ..	100	1·25	0·57
		Frozen at −9° C. for thirty-seven days	100	..	0·58
4/3/42	Four months after sowing (9 in. high), local plot	Boiling alcohol	500	1·15	0·36
		Frozen at −22° C. for nine days	150	0·81	0·34
7/4/42	Eight months after sowing (9 in. high), local plot	Boiling alcohol	250	1·28	0·43
		Bottled, 100° C. (stored for thirty-six days)	454	0·89	0·30
		Bottled, 120° C. (stored for thirty-six days)	454	0·49	0.76
4/12/41	Six months after sowing (flush growth after rain, 6 in. to 7 in. high), Palmerston North	Boiling alcohol for one hour ..	18,140	1·51	0·39
		Boiling water and then steamed for several days	23,270	0·82	1·47
20/8/42	Nine months after sowing (7 in. to 14 in. high), local plot	Boiling alcohol	227	..	0·26
		Boiling water for two hours ..	227	1·76	0·41
		Boiling water for four hours ..	227	1·55	0·37
		Boiling water at 105° for two hours	227	1·70	0·51
		Boiling water at 120° for two hours	227	0·64	0·67

TABLE 1B.—FREE FATTY ACIDS AND PHOSPHATIDES EXPRESSED AS A PERCENTAGE OF THE VALUES GIVEN BY THE ALCOHOL TREATMENT

Treatment.	Time of Treatment.	Time of Storage.	Free Fatty Acid.	Phosphatides.
Boiling alcoho	Twenty minutes	..	100	100
Boiling water	Twenty minutes	..	·255, 212*	106, 71*
Boiling water	Twenty minutes†	Thirty-six days (bottled) ..	70	70
Boiling water	Twenty minutes†	Thirty-six days (bottled) ..	180	38
Boiling water	Two hours ..	..	158	..
Boiling water	Four hours ..	..	142	..
Boiling water, 105° C. ..	Two hours ..	..	196	..
Boiling water, 120° C. ..	Two hours ..	..	258	..
Frozen at −9° C. ..	..	Ten days	178	57
Frozen at −9° C. ..	..	Fourteen days	81	68
Frozen at −9° C. ..	..	Thirty-seven days ..	181	..
Frozen at −22° C. ..	..	Nine days	95	70
Dried at 38° C.	..	..	158	26
Dried at 105° C. ..	Twenty-four hours	..	280	56

* These figures do not represent duplicate determinations, but were obtained on separate samples at different times.

† Denotes that the treatment was repeated on the following day.

TABLE 1C.—ASCORBIC ACID

Treatment.	Milligram Percentage on Wet Weight.	Expressed as a Percentage of the Ascorbic Acid Content of Fresh Grass.
Fresh grass	75·5	100
Boiling alcohol	58·0	77
Boiling water, twenty minutes	47·8	63
Fresh grass	37·6	100
Frozen at −9° C. for ten days	0·3	0·7
Fresh grass	40·0	100
Boiling alcohol	22·2	56
Boiling water, two hours	12·3	31
Water at 105°, two hours	16·4	40
Water at 120°, two hours	16·3	40

TABLE 1D.—REDUCING SUGAR

(Expressed as a Percentage of Dry Weight)

Treatment.	Before Hydrolysis.	After Hydrolysis.
Boiling alcohol	0·26	4·13
Boiling water, two hours	0·66	4·18
Boiling water, four hours	0·52	4·00
Boiling water 105° C., two hours	0·54	4·01
Boiling water 120° C., two hours	0·62	4·19

In evaluating the results given in Table 1A it is necessary to take into consideration certain complicating factors. Only samples cut at the same time are comparable in all respects, and comparisons between samples cut at different times may not be valid. In the event of the hydrolysis of the lipids occurring during preservation treatment the free fatty acids may either form soaps (32), which would not be extracted with petroleum ether, or combine with organic materials. The results may also be complicated by the fact that the enzymes affecting the components studied—*i.e.*, free fatty acids, phosphatides, sugars, and vitamin C—may vary in absolute and relative amounts in different samples. In the interpretation of the results only major differences can be considered significant.

The highest values for phosphatides were obtained with the boiling-alcohol treatment, but in some cases the boiling-water treatment was as effective (Table 1A). This seems to indicate that the phosphatides in certain circumstances are stable towards heat. Prolonged heating at 120° (cf. Table 1A), however, appears to cause breakdown of the phosphatide molecule. A similar effect was noted in a sample which had been steamed for several days. The free fatty acid content in the case of the boiling-water treatments, without storage, was from 1·4 to 2·6 times greater than was found for alcohol preserved samples (Table 1B). The free fatty acid value of the grass preserved by heating in water at 100° C. and bottling for thirty-six days is anomalous, being lower than that found for the alcohol control sample. Freezing at −9° C. resulted in loss of phosphatides, and in two of the three trials greatly increased the free fatty acid content, but in one trial the free fatty acid was low, as compared with the value for the alcohol preserved samples. Freezing at −22° C. resulted in 30 per cent. loss of phosphatide but no gain in free fatty acid. It is conceivable that the grass is not immediately killed on freezing and that metabolic processes continue, resulting in the utilization and/or production of constituents.

Sterilization of the grass with boiling alcohol or with boiling water for twenty minutes were the most satisfactory treatments for the preservation of ascorbic acid. Freezing at −9° C. for ten days resulted in almost complete destruction of vitamin C (Table 1C).

Grass subjected to boiling alcohol or to boiling-water treatment had only a small proportion of dehydroascorbic acid. However, grass autoclaved at 105° C. and 120° C. contained 4·4 mg. and 6·2 mg. per cent. (Table 1C) respectively of dehydroascorbic acid, bringing the total ascorbic acid up to that of the alcohol preserved sample (22·2 mg. per cent.).

Apart from the relatively low value (Table 1D) for the free sugar from the boiling alcohol treatment there was no significant difference between the treatments in regard to sugar content. It is possible that the boiling with water resulted in the hydrolysis of some carbohydrate—*e.g.*, glucoside—or else the boiling alcohol more rapidly arrested enzyme action by quicker penetration of the tissues.

More detailed work on the drying of grass was done subsequently to the above results and is set out below. The object of these experiments was to compare grass preserved in boiling alcohol with dried grass, and to study the effect of the size of the sample and of storage on the ascorbic acid, total lipid, phosphatide, free fatty acid, and free sugar content. The grass used was cut at 6 a.m. with a motor-mower, thoroughly mixed, and the weighed samples transferred to the drier or to the boiling alcohol with minimum delay. To evaluate the sampling errors twenty-four separate samples were prepared, and for these three were selected at random for each treatment. An analysis of variance(33, 34) was made of the results.

TABLE 2A.—WAIROA PASTURE: ASCORBIC ACID (MILLIGRAM PERCENTAGE OF DRY WEIGHT)

	Fifteen Days' Storage.				Thirty-six Days' Storage.			
	Boiling Alcohol.		Dried.		Boiling Alcohol.		Dried.	
	1 lb.	10 lb.	1 lb.	10 lb.	1 lb.	10 lb.	1 lb.	10 lb.
	29·2	30·3	19·2	43·8	22·4	16·8	4·7	7·0
	36·2	30·5	26·0	38·2	40·0	15·2	3·6	8·4
	29·4	43·7	16·1	56·5	21·0	20·5	1·5	15·4
Means	31·6	34·6	20·4	46·2	27·8	17·5	3·4	10·3

Fresh grass contained 377 mg. per cent. on the dry weight.

The results of Table 2A show that, irrespective of the method of storage, the ascorbic acid content decreased significantly in the course of time, the effect being more pronounced in the dried samples as compared with those stored in alcohol. The 10 lb. dried samples contained more ascorbic acid than the 1 lb. dried samples, after the same period of storage, the ascorbic acid content of the former being relatively less affected by storage.

TABLE 2B.—WAIROA PASTURE: TOTAL LIPID (PERCENTAGE OF THE DRY WEIGHT)

Fifteen Days' Storage.				Thirty-six Days' Storage.			
Boiling Alcohol.		Dried.		Boiling Alcohol.		Dried.	
1 lb.	10 lb.	1 lb.	10 lb.	1 lb.	10 lb.	1 lb.	10 lb.
11·3	10·9	8·3	9·7	8·3	7·4	8·3	8·1
8·9	9·0	7·2	10·2	6·8	8·2	8·1	8·9
7·6	10·5	8·8	9·2	9·4	6·9	7·7	9·2
Means 9·3	10·1	8·1	9·7	8·2	7·5	8·0	8·7

The alcohol preserved samples after fifteen days' storage contained significantly more total fat than any of the other samples. The alcohol preserved samples after thirty-six days' storage and all the dried samples did not differ from one another significantly. Presumably drying or standing in alcohol for lengthy periods renders a portion of the lipids insoluble in petroleum ether.

TABLE 2C.—WAIROA PASTURE: PETROLEUM ETHER SOLUBLE PHOSPHORUS (MILLIGRAM PERCENTAGE OF THE DRY WEIGHT)

Fifteen Days' Storage.				Thirty-six Days' Storage.			
Boiling Alcohol.		Dried.		Boiling Alcohol.		Dried.	
1 lb.	10 lb.	1 lb.	10 lb.	1 lb.	10 lb.	1 lb.	10 lb.
83	72	45	57	57	50	43	40
47	71	31	81	34	56	39	54
48	37	47	92	60	41	39	55
Means 59	60	41	77	50	49	40	50

There was significantly less petroleum ether soluble phosphorus after thirty-six days' as compared with fifteen days' storage. There appeared to be no significant difference in the petroleum ether soluble phosphorus content in the alcohol preserved as compared with the dried grass. The 10 lb. dried grass contained highly significantly more petroleum ether soluble phosphorus than the 1 lb. dried samples. This could be due to the 1 lb. samples being over heated, rendering the phosphatides less soluble in petroleum ether.

TABLE 2D.—WAIROA PASTURE: FREE FATTY ACIDS (PERCENTAGE OF DRY WEIGHT AND CALCULATED AS OLEIC ACID)

Fifteen Days' Storage.				Thirty-six Days' Storage.			
Boiling Alcohol.		Dried.		Boiling Alcohol.		Dried.	
1 lb.	10 lb.	1 lb.	10 lb.	1 lb.	10 lb.	1 lb.	10 lb.
2·00	1·02	0·79	0·73	0·71	0·68	0·94	0·80
1·65	0·58	0·49	0·38	0·84	0·98	0·61	0·75
0·74	1·11	0·47	0·73	1·10	0·64	0·26	0·61
Means 1·46	0·90	0·58	0·61	0·88	0·77	0·60	0·72

The dried samples contained less free fatty acid than the alcohol preserved samples, this difference being highly significant. No other differences were significant.

TABLE 2E.—WAIROA PASTURE: FREE SUGAR (AS GLUCOSE), (PERCENTAGE OF THE DRY WEIGHT)

Fifteen Days' Storage.				Thirty-six Days' Storage.			
Boiling Alcohol.		Dried.		Boiling Alcohol.		Dried.	
1 lb.	10 lb.	1 lb.	10 lb.	1 lb.	10 lb.	1 lb.	10 lb.
0·65	0·70	0·32	0·32	0·36	0·91	0·50	2·84
0·56	0·81	0·42	0·34	0·49	0·43	1·17	1·46
0·59	0·86	0·19	0·17	0·74	0·61	0·27	1·81
Means 0·60	0·79	0·31	0·28	0·53	0·65	0·65	2·09

The free sugar content of the alcohol preserved samples was higher initially than that of the dried samples, but did not increase on storage and was unaffected by the size of the sample. On storage for thirty-six days the free sugar content of the dried samples increased, the effect being especially marked in all 10 lb. samples and in one of the 1 lb. samples.

Attention is drawn to the wide variations in the results for the storage of dried samples, which are especially noticeable in the 10 lb. samples. The cause of these variations is obscure. The absorption of moisture (approximately 12 per cent.) by dried samples would no doubt facilitate the production of free sugar. The greater insulating effect of the 10 lb. samples as compared with the 1 lb. samples might enable better retention of heat produced in the event of bacterial action.

TABLE 3A.—RUAKURA DRIED GRASS: EFFECT OF SIZE OF SAMPLE AND TEMPERATURE

Weight of Grass.	Time taken to Dry.	Temperature below Tray.	Vitamin C Content (Milligram Percentage of Dry Weight).		
			Fresh Grass.	Dried Grass.	Percentage of Fresh Grass.
lb.	Min.	°C.			
100	90	90	765	410	54
100	60	120	874	654	75
25	20	120	714	613	86
10	10	120	624	595	95

TABLE 3B.—RUAKURA DRIED GRASS: EFFECT ON STORAGE

—	Vitamin C Content (Milligram Percentage of Dry Weight).	
	After Fourteen Days' Storage.	After Thirty-six Days' Storage
25 lb. dried grass stored in sack	332	160
10 lb. dried grass stored in sack	224	189
Dried grass pressed into bale	261	94

It is evident from the present work that although dried grass may be superior immediately after drying to the alcohol preserved samples, its keeping-qualities when kept in sacks or bales are very poor in respect to vitamin C preservation.

In the interpretation of these results the size of the samples has an important effect (this is illustrated by Table 3A). To secure the best results when drying or freezing, the material must be spread in thin layers to effect rapid heat exchange. If means of preserving dried grass such as vacuum containers or carbon dioxide atmosphere could be devised, drying might prove to be as good or better than boiling alcohol.

When cut grass was stored inside away from direct sunlight it was found in earlier unpublished studies that the chlorophyll content increased by 10 per cent. after the first day's storage, returning to the original value two days after cutting. Carotene was not appreciably affected under these conditions, while the non-protein nitrogen determined after twenty-four hours' storage showed an increase of about 17 per cent. based on the value for the freshly cut grass.

It is therefore important to distinguish between a state of preservation in which the plant continues to live and a state of preservation which prevents changes in the quality and quantity of the constituents originally present in the plant.

CONCLUSIONS

In preparing samples for chemical analysis, preservation in boiling alcohol would seem to be the most satisfactory process in the majority of circumstances, should the alcohol and equipment be available. It is recommended that the intact leaves should be dropped into boiling alcohol and the boiling continued for twenty minutes. Failing this, boiling water can be used as an effective preservative if the necessary conditions are observed. For further storage the contents should be transferred to an airtight container.

Freezing is not satisfactory, unless it is rapid and the final temperature is low enough (at least −20° C.). High temperature drying seems to offer good possibilities in regard to the preservation of certain constituents. A drier which rapidly heats the tissue to 100° would rapidly inactivate enzyme action. This may be achieved by exposing thin layers of grass to a rapid current of air heated to 120°. On the other hand, a drier in which the leaf-tissues remained at a lower temperature—*e.g.*, 35° C.—might well result in destruction of constituents or in the production of new substances during the drying process.

To dry grass in a satisfactory condition it is recommended to use in the early stages a current of air at 120° C. until the moisture content reaches 10 per cent. and to finish the drying at 60° to 70° C.(35). Grass containing less than 4 per cent. moisture will keep well(12). Any increase in moisture

content affects the keeping-qualities, and as dried grass will absorb from the atmosphere approximately 10 per cent. water, it is not feasible to store dried grass without appreciable changes in certain constituents, except in air-tight containers.

ACKNOWLEDGMENTS

We wish to acknowledge the helpful criticism and advice given by Mr. R. E. R. Grimmett, Chief Agricultural Chemist, Department of Agriculture. Our thanks are also due to the Director, Dr. J. Melville, Plant Chemistry Laboratory, Palmerston North, for supplying samples of rye-grass.

REFERENCES

(1) H. E. WOODMAN (1935): *J. Min. Agr.*, *41*, 1049.
(2) S. BARTLETT, K. M. HENRY, S. K. KON, L. W. OSBORNE, S. Y. THOMPSON, and J. TINSLEY (1938): *Biochem. J.*, *32*, 2024.
(3) W. H. CASHMORE (1943): *Chem. and Ind.*, *62*, 278.
(4) C. G. KING and D. K. TRESSLER (1940): *Proc. 1st Food Conf. Inst. Food Tech.*, *1*, 123; *Chem. Abstract* (1941), *35*, 2617.
(5) W. DIEMAIR, E. TIMMLING, and H. FOX (1939): *Vorratspflege u Lebensmittelforsch*, *2*, 152; *Nut. Abstract and Rev.* (1939), *9*, *97*.
(6) W. V. CRUESS and M. A. JOSLYN (1942): *Proc. Inst. Food Tech.*, 99.
(7) V. A. BECKLEY and V. E. NOTLEY (1941): *Biochem. J.*, *35*, 1396.
(8) H. DILLER (1941): *Vorratspflege u Lebensmittelforsch 4*, 389; *Chem. Abstract* (1943), *37*, 2479.
(9) D. K. TRESSLER (1942): *New York State Agr. Expt. Station. Tech. Bull. No. 262.*
(10) M. B. DAVIS, C. G. EIDT, M. MCARTHUR, and C. C. STRACHAN (1942): *Proc. Inst. Food Tech.*, 90.
(11) W. R. AYKROYD (1943): *Nature*, *151*, 22.
(12) H. R. MARSTON, F. QUINLAN-WATSON, and D. F. DEWEY (1943): *Aust. J. Council Sci. Ind. Res.*, *16*, 113.
(13) J. BARKER and T. N. MORRIS (1937): *Dept. Sci. Ind. Res. (Brit.) Rep. Food Invest. Board*, 190.
(14) E. N. TODHUNTER and R. C. ROBBINS (1941): *Wash. Agr. Expt. Station Bull. No. 408.*
(15) M. OLLIVER (1943): *Chem. and Ind.*, *62*, 146.
(16) T. N. MORRIS and J. BARKER (1933): *Dept. Sci. Ind. Res. (Brit.) Rep. Food Invest. Board*, 80.
(17) F. KROKER (1939): *Med. Welt.*, *13*, 123; *Chem. Abstract* (1939), *33*, 4327.
(18) J. BARKER and T. N. MORRIS (1938): *Dept. Sci. Ind. Res. (Brit.) Rep. Food Invest. Board*, 209.
(19) "Canned Food Reference Manual"; American Can Company, New York.
(20) C. F. DUNKERS and C. R. FELLERS (1939): *Proc. Am. Soc. Hort. Sci.*, *36*, 500.
(21) W. E. LOOMIS and C. A. SCHULL (1937): "Methods in Plant Physiology." McGraw Hill, New York.
(22) W. A. DAVIS, A. J. DAISH, and G. C. SAWYER (1916): *J. Agr. Sci.*, *7*, 255.
(23) R. R. BRIESE and J. F. COUCH (1938): *J. Agr. Res.*, *57*, 81.
(24) J. A. B. SMITH and A. C. CHIBNALL (1932): *Biochem. J.*, *26*, 1345.
(25) F. B. SHORLAND (1941): *N.Z. J. Sci. & Tech.*, *23*, 112A.
(26) ——— (1944): *Nature*, *153*, 168.
(27) B. W. DOAK (1939): *N.Z. J. Sci. & Tech.*, *21*, 90B.
(28) P. A. SHAFFER and M. SOMOGYI (1933): *J. Biol. Chem.*, *100*, 695.
(29) N. C. THORNTON (1938): *Contributions from the Boyce Thompson Institute*, *9*, *No. 4*, 273.
(30) M. H. MESSAKER and N. B. GUERRANT (1938): *J. Ind. Eng. Chem. (Anal. Ed.)*, *10*, 25.
(31) E. W. MCHENRY and M. GRAHAM (1935): *Biochem. J.*, *29*, 2013.
(32) J. A. LOVERN (1942): *Dept. Sci. Ind. Res. (Brit.) Rept. Food Invest. Board, Special Rept. No. 52.*
(33) R. A. FISHER (1934): "Statistical Methods for Research Workers." Oliver and Boyd, Edinburgh.
(34) D. D. PATERSON (1939): "Statistical Technique in Agricultural Research." McGraw-Hill Book Co., Inc., New York.
(35) R. T. L. ALLEN, J. BARKER, and L. W. MAPSON (1943): *J. Soc. Chem. Ind.*, *62*, 145.

SOME STUDIES ON THE PROPERTIES OF RUBBER USED IN DAIRY EQUIPMENT

PART II

By W. G. WHITTLESTON, Animal Research Station, Wallaceville

(*Continued from Vol. 26, No. 5 (A Sect.), February, 1945, p. 252*)

SOME EXPERIMENTS ON THE SUITABILITY OF DIFFERENT RUBBER STOCKS AND TYPES OF RUBBERWARE FOR USE ON MILKING MACHINERY

INFLATIONS

The following are the results of an investigation into the relative advantages of light moulded over soft inflations.

Flexing-test Results

The following are the results of flexing tests on a collection of inflations of both types made by three different manufacturers :—

No.	Length of Crack (Inches).	
	Light Moulded.	Soft.
1	0·8	1·8
2	3·0	2·2
3	1·0	0·0
4	2·3	0·6
5	0·1	0·3
6	5·0	4·6
7	4·3	3·9
8	2·5	5·1
9	1·1	4·2
Means	2·2	2·5

It is evident on inspection that there is no significant difference between the two types.

Field Tests

For the type of light moulded inflation tested above we have obtained under good shed conditions a life of 122 days. Soft inflations of the same make under the same conditions gave an average life of 93 days. These figures are fairly typical of the difference in life of the two types. The light moulded inflation does not deteriorate round the top as quickly as the soft inflation, as it is shaped to fit the ring and is hence not held under tension. Further, the rubber lip is somewhat thicker.

The Effect of the Addition of a Small Amount of Reclaim to Inflation Rubber

The inflations used in this experiment were of make C and of two types: light moulded and soft. The two types will be discussed separately.

Light Moulded Inflations.—The field trials were carried out in the main shed at Massey Agricultural College, where conditions are good and uniform.

The inflations were fitted to two sets of cups so that there were two normal inflations and two containing reclaim in each set. All inflations were weighed at the beginning of the experiment and the absorption of fat

determined by washing with a detergent mixture in hot water and drying in the air oven before weighing.

The machine to which the inflations were fitted operated at a 13 in. to 14 in. vacuum, a pulsator rate of 40, and a ratio of 40 : 60. The machine was washed twice daily with a detergent containing soda ash, sodium metasilicate, trisodium phosphate, and sodium sulphite.

The following figures indicate the rate at which the two groups of inflations absorbed fat and the actual working life of this type of inflation :—

No.	Description.	Weight at Start.	Weight after Fifty-three Days.	Percentage Increase.	Weight at End of Useful Life.	Percentage Increase.	Life (Days).
		g.	g.		g.		
(a) 1	+ 8 per cent. black reclaim	33·159	42·094	26·94	44·889	35·38	79 (X)
2	Ditto	35·527	45·031	26·75	47·632	34·08	79 (X)
3	Control (normal red) ..	32·906	37·776	14·79	42·094	27·92	123 (Y)
4	,, ..	34·085	40·657	19·28	45·293	32·88	123 (Y)
(b) 1	+ red reclaim ..	34·663	39·183	13·04	43·652	25·96	123 (Y)
2	,, ..	33·442	39·496	18·05	42·844	28·13	100 (X)
3	Control	34·179	38·940	13·94	43·088	26·20	123 (Y)
4	,, ...	33·661	38·419	14·14	43·252	28·50	123 (Y)

NOTES.—Those samples marked (X) ended their useful life due to flex cracking. Samples marked (Y) were discarded due to bulging and perishing round the tops.

The following are the details of the inflations developing cracks :—

No.	Total Length of Cracks (Inches).	Condition.
(a) 1	1·5	Somewhat bulged.
2	1·3	,,
(b) 2	0·5	,,

When the four inflations containing reclaim are compared with the four controls after fifty-three days' use the mean difference ($\overline{X}$) = 5·7, while the standard deviation (S) = 4·8. This indicates that the differences do not quite reach the 5 per cent. probability level. If computed for the two pairs in the (a) group the mean difference = 9·8, while the standard deviation = 3·32, which almost reaches the 5 per cent. probability level. The results may be said to indicate but not definitely prove, that under the conditions of the experiment, the rubber containing reclaim tended to absorb butterfat and hence to swell and bulge more than normal rubber. There is no significant difference at the end of the life of the inflations.

Life of Inflations tested : There is a significant difference between the lives of the pairs in group (a) (rubber containing black reclaim and normal red rubber), but none in the case of group (b).

General Condition : The following notes summarize the general condition of the inflations marked Y :—

(a) 3 .. Perished round tip. Walls slightly sticky. Total length of flex cracks = 1·5 in.
(a) 4 .. Similar to (a) 3, but has flex cracks totalling 0·6 in.
(b) 1 .. Similar to (a) 3, but has no flex cracks.
(b) 3 .. Similar to (a) 3, has no flex cracks, but there is a flaw in the wall.
(b) 4 .. Similar to (a) 3, but has flex cracks totalling 0·6 in. and is not quite as sticky as (a) 3.

Soft Inflations.—Soft inflations made of the same mix as that described above as "+ red reclaim" were compared with normal inflations of the same make in the following tests :—

Fat Absorption: This test was carried out as described previously with the results set out in the accompanying figure (Fig. 9). Samples 1 and 2 contained reclaim. It appears that the addition of a small amount of reclaim increases the tendency of the rubber to absorb butterfat.

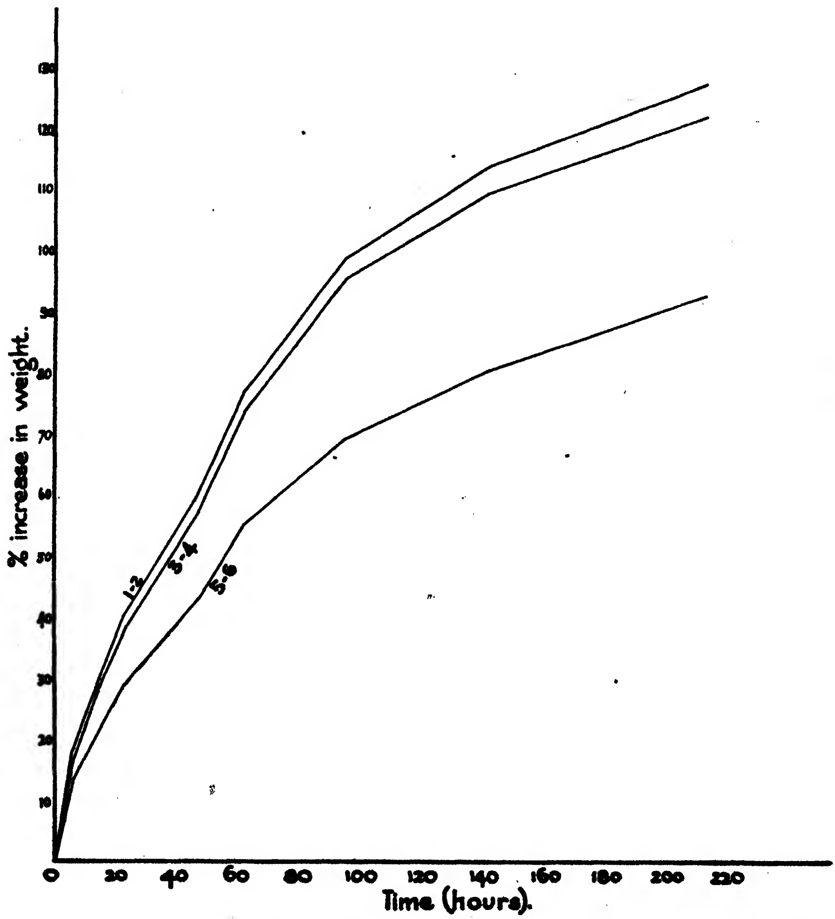


FIG. 9.—Fat-absorption curves (inflation rubbers): 1, 2, rubber containing reclaim, make C; 3, 4, normal rubber, make C; 5, 6, normal rubber, make A.

Flexing Tests: The above rubbers were subjected to flexing tests, with the following results :—

Make C—	Length of Crack (Inches).
No. 1 (+ reclaim)—	
(*a*)	0·6
(*b*)	2·0
No. 2 (control)—	
(*a*)	3·5
(*b*)	4·2

The mean differences for the above results in 2·6 in favour of No. 1 samples, while the standard deviation is 0·5. The difference just reaches

significance. A small amount of reclaim improves the flexing qualities of rubber.

Permanent Set: Permanent-set determinations were carried out using the methods described above. The elongation was 550 per cent. The following results were obtained :—

	Permanent Set (per Cent.).
No. 1 (+ reclaim)—	
(a)	6·54
(b)	6·54
No. 2 (control)—	
(a)	5·12
(b)	4·67

The permanent set of the rubber has apparently been slightly increased by the addition of a small amount of reclaim.

The Characteristics of a Series of Experimental Rubber Stocks.—This series consisted of four experimental rubbers and a normal as control. Fat absorption and tensile strengths were determined on $\frac{7}{8}$ in. by $\frac{1}{8}$ in. by $\frac{3}{32}$ in. rings. Fat absorption was tested at 45°.

The following are the characteristics of the rubbers used in the test :—

No.	Breaking Load of Rings (Kilograms).	Shore Hardness.	Total Fillers (per Cent.).	Colour.
1 ..	19·2	51	50·8	Green.
2 ..	20·3	47	40·4	Grey.
3 ..	27·4	42	21·6	Pink.
4 ..	22·4	46	..	Black (carbon black).
5 ..	21·6	46	33·9	Red.

The accompanying figure (Fig. 10) gives the fat-absorption curves for the above rubbers. The final breaking loads for the samples after immersion for 117·74 hours in butterfat at 45° C. were :—

No.	Breaking Load (Kilograms).
1	7·0
2	3·5
3	3·7
4	4·7
5	13·7

The results of flexing tests and field trials are set out in the following table :—

No.	Length of Cracks (Inches).	Field Life (Days).	Percentage Fat absorbed.	Flex Cracks on discarding (average of Two Samples), (Inches).
1 ..	4·5	78	12·6	0·5
2 ..	0·1	85	17·2	0·7
3 ..	0·0	87	20·7	0·0
4 (a) ..	0·0	..	..	..
(b) ..	1·6			
5 (a) ..	1·1	87	15·9	0·25
(b) ..	2·1			

Only one sample of each (except the controls and carbon-black samples) was available for flexing tests. As the carbon-black samples were tested

in another experiment under slightly different shed conditions, the results are not given in this table. The maintenance of constant shed conditions is extraordinarily difficult and hence only when a group has been tested together can comparison be made with any accuracy.

DISCUSSION

The fat-absorption curves show that, for each type of rubber, fat absorption increases with decreasing hardness. Carbon-black rubber is interesting in that it shows a greater rate of fat absorption than a normal rubber of the same hardness. The effect of butterfat on the breaking load of the rings is very marked. Generally, the normal red rubber has put up the best all-round performance. The rapid fat absorption of the carbon-black and soft

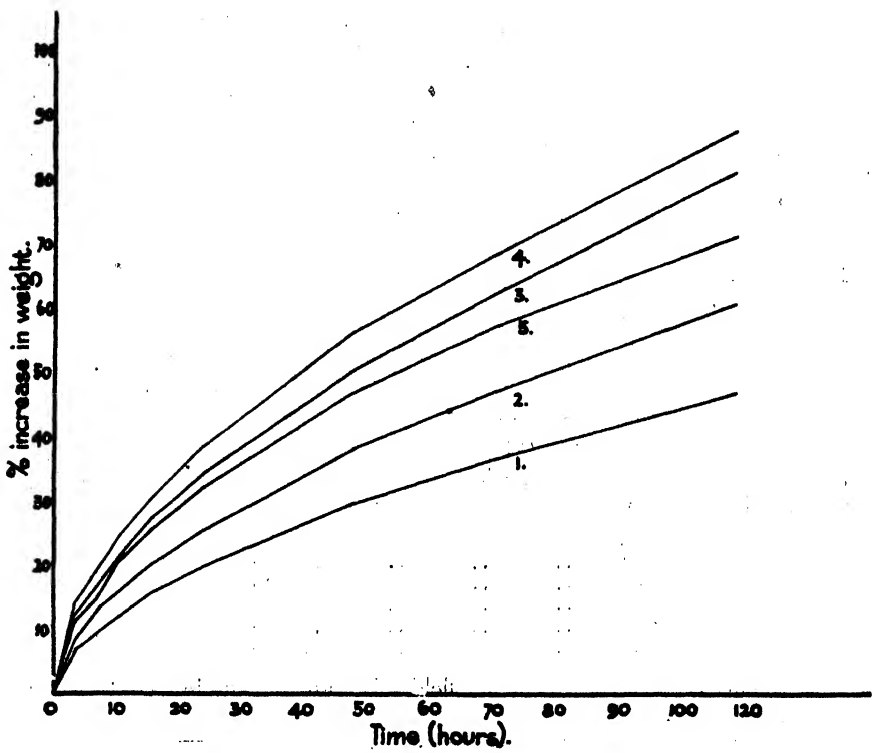


FIG. 10.—Fat-absorption curves for a series of experimental rubber stocks.

pink stocks is unsatisfactory, while the poor flexing life of the hard stock, No. 1, caused it to have a shorter life than the rest.

AN EXAMINATION OF THE MERITS OF SMOOTH FINISH AND CARBON-BLACK INFLATIONS

The excellent results obtained on a flexing test with an inverted normal inflation gave rise to the belief that if an inflation with the same physical properties as a normal one but with a smooth exterior could be made, the flexing life would be improved and it would be easier to clean. One manufacturer devised a way of making such inflations. These were tested under

typical field conditions together with carbon-black rubbers. The following are the results of our tests on these rubbers :—

Type.	Flexing Test : Length of Cracks (Inches).	Permanent Set (per Cent.).	Field Life (Days).	Cracks on discarding (Inches).	Percentage Fat absorbed.
Smooth ..	4·4	12·49	109	1·4	15·86
	5·7	..	122	0·9	16·08
	4·5	..	129	0·4	
	2·0	..	94	0·6	Av. 15·97
Carbon black ..	0·0	8·84	118	0·5	20·18
	1·6	..	114	0·0	16·34
	1·4	..	106	0·0	
	0·3	..	169	0·5	Av. 18·26
Normal controls..	2·1	21·07	153	1·0	20·73
	1·9	..	111	1·1	21·50
	1·3	..	126	0·9	
	0·2	..	..	..	Av. 21·12

The smooth inflations are evidently not made of a rubber which is comparable with the normal type. This is most clearly seen in the difference in permanent set. Hence, the poorer flexing properties can hardly be due to the smooth finish—the opposite should be true. The poor flexing properties of the smooth inflations are unfortunate, as these samples had to be discarded due to flex cracking before they had become flabby and very dirty. The carbon-black inflations put up a good performance, but were flabby when removed. The absorption of butterfat in this case has a more marked effect on the physical properties—*e.g.*, tensile strength—than in the case of normal rubbers with a fine clay filler. This experiment indicates that unless carbon-black stocks are made with a greater hardness in order to increase their butterfat resistance they are no more satisfactory in use than normal stocks.

THE LIGHT-AGEING RESISTANCE OF A GROUP OF INFLATION RUBBERS

In the light of the results of earlier light-ageing experiments the following test was devised as a simple comparative light-ageing test.

A weatherproof box with ample cross ventilation was fitted with a "Perspex" top. This box was placed on the top of the laboratory building in a place where no direct sunlight could influence it. Rubber samples were placed on glass plates as in previous experiments and suspended in the middle of the box, one side being kept towards the top. This meant that one side received direct sky light, the other being subject to diffuse light reflected from the grey paint on the interior walls of the box.

One-half of the samples were treated with butterfat by dipping them for three hours in butterfat at 45° C. In order to have smooth surfaces for the experiment, the rings were turned inside out.

The samples were exposed between 23rd November and 14th December, 1943—twenty-one days. The total radiant energy during this period was 13,644 g. cal./sq. cm. and the total sunshine 173 hours.

The transmission of the "Perspex" used in the ultra-violet region is given by the accompanying graph (Fig. 11).

The accompanying photomicrographs (Fig. 12, *a*, *b*, and *c*) illustrate the condition of the surfaces after the above treatment.

The rubbers used were the following :—

Make D : Carbon black ; pink ; grey ; green ; normal (red).
Make A : Grey.
Make B : Normal.
Make C : Normal.

All rings were ⅛ in. wide and cut from standard inflations.

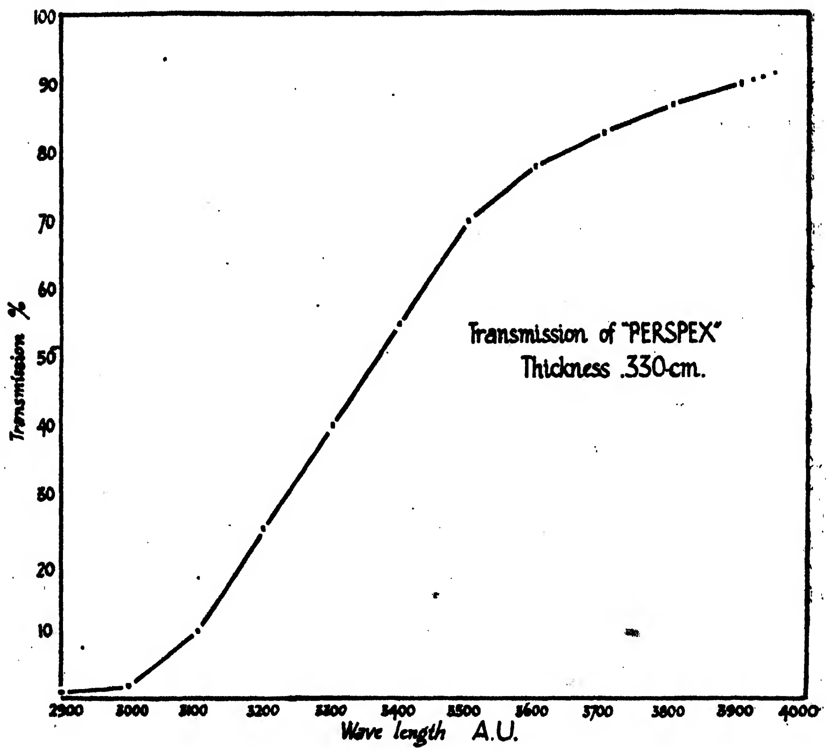


FIG. 11.

Notes on photomicrographs :—

No.	Make.	Treatment.	Remarks.
1	C	Fat ..	Deep cracking partly across sample. Surface roughened.
2	B	„ ..	Very deep cracks across sample.
3	A	„ ..	No change.
4	C	Control ..	Tendency to crack developing.
5	B	„ ..	Slight roughening.
6	A	„ ..	No change.
7	D (green) ..	Fat ..	Deep longitudinal cracks developed.
8	D (c, b,) ..	„ ..	Sharp-edged regular deep transverse cracks. These do not run right across sample and are characteristic in shape for this rubber.
9	D (normal) ..	„ ..	No change.
10	D (grey) ..	„ ..	Surface holes just showing—probably incipient cracks.
11	D (pink) ..	„ ..	Only one small crack at edge of sample ; otherwise unchanged.
12	D (green) ..	Control ..	Unchanged.
13	D (carbon black)	„ ..	Signs of incipient cracking.
14	D (pink) ..	„ ..	Unchanged.
15	D (normal) ..	„ ..	„
16	D (grey) ..	„ ..	„

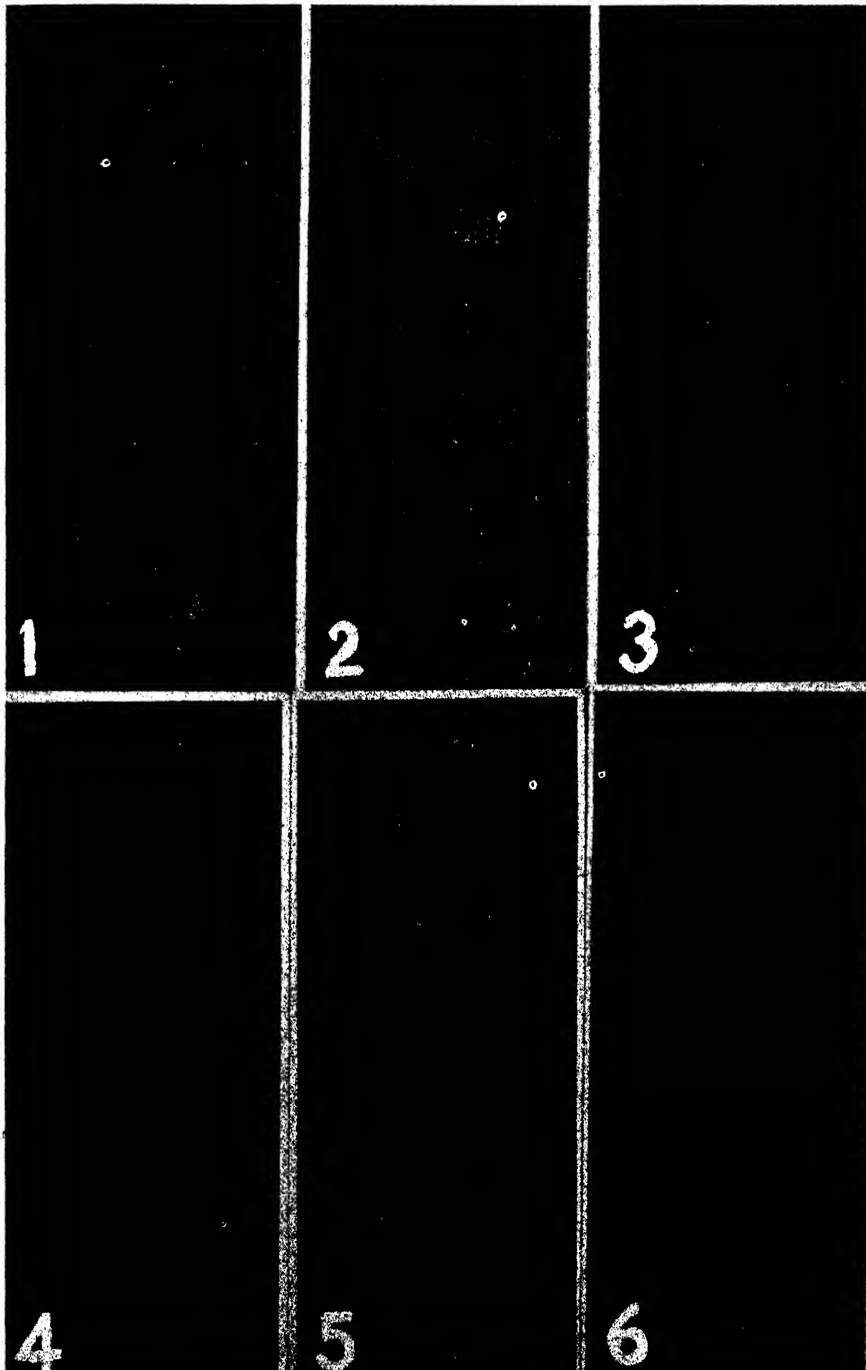


FIG. 12 (a).

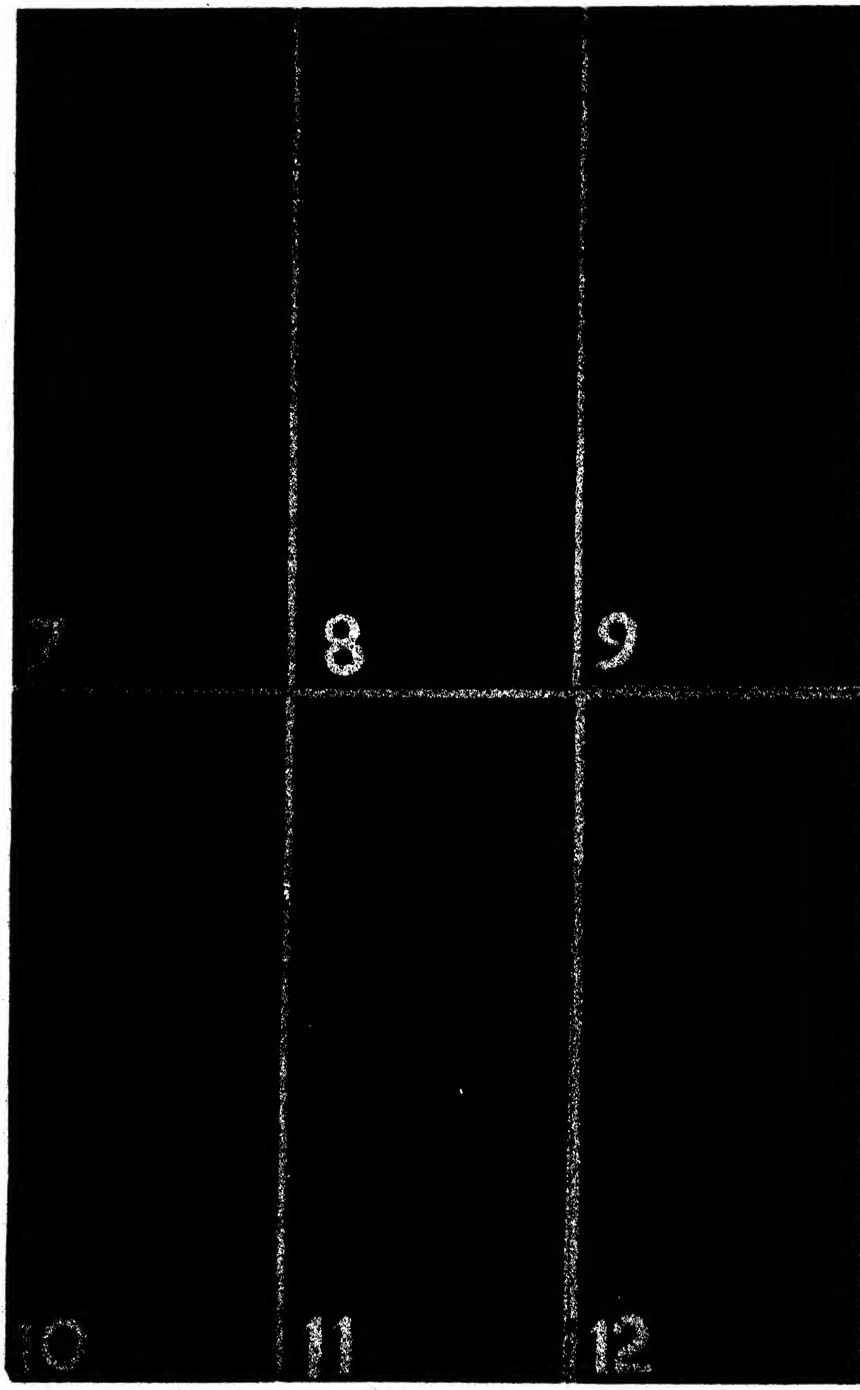


FIG. 12 (b).

DISCUSSION

It is evident once more that butterfat greatly influences the resistance of rubbers generally to light ageing. Further, under "Perspex," ageing takes place at approximately twice the rate obtained under window glass

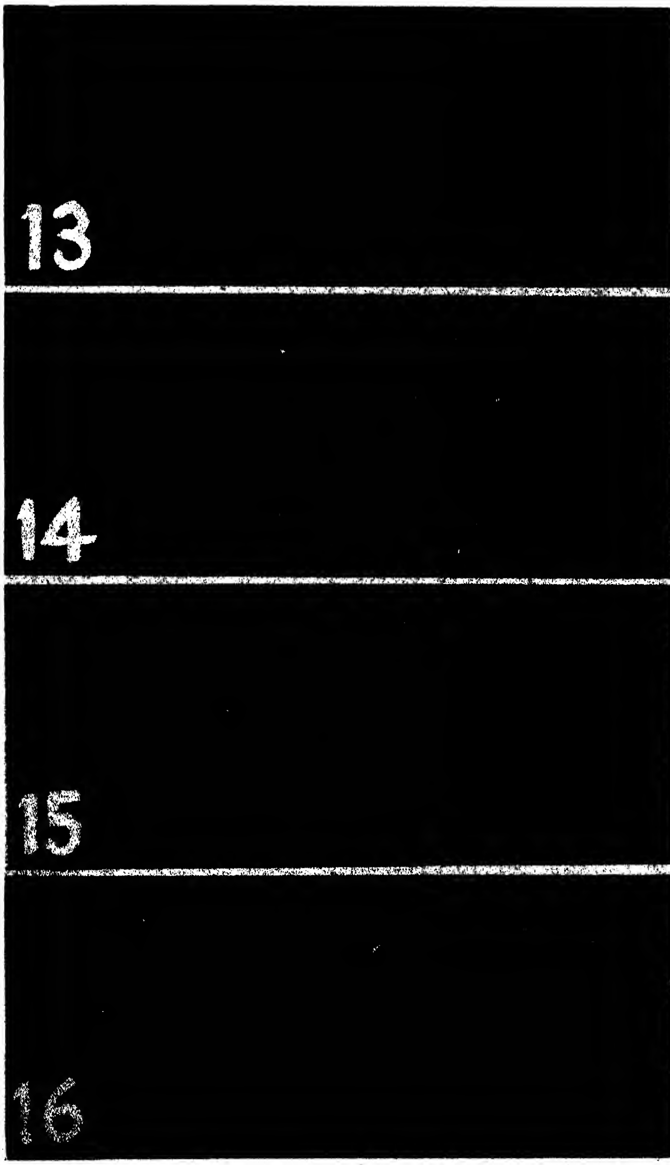


FIG. 12 (c).

(twenty-one days produce almost as much cracking as forty days under window glass, despite the fact that the previous samples under glass were exposed to direct sunlight). There is a very wide range of differences between

different stocks in resistance to fat and light ageing. Make B and make C rubbers are poor, while make A is excellent. Make D green and carbon black, though not as badly aged as make B and make C, are nevertheless not good. Make D normal and grey are excellent.

The above considerations are important in view of the fact that the life of inflations under field conditions is frequently governed by the light resistance of the rubber in the presence of butterfat.

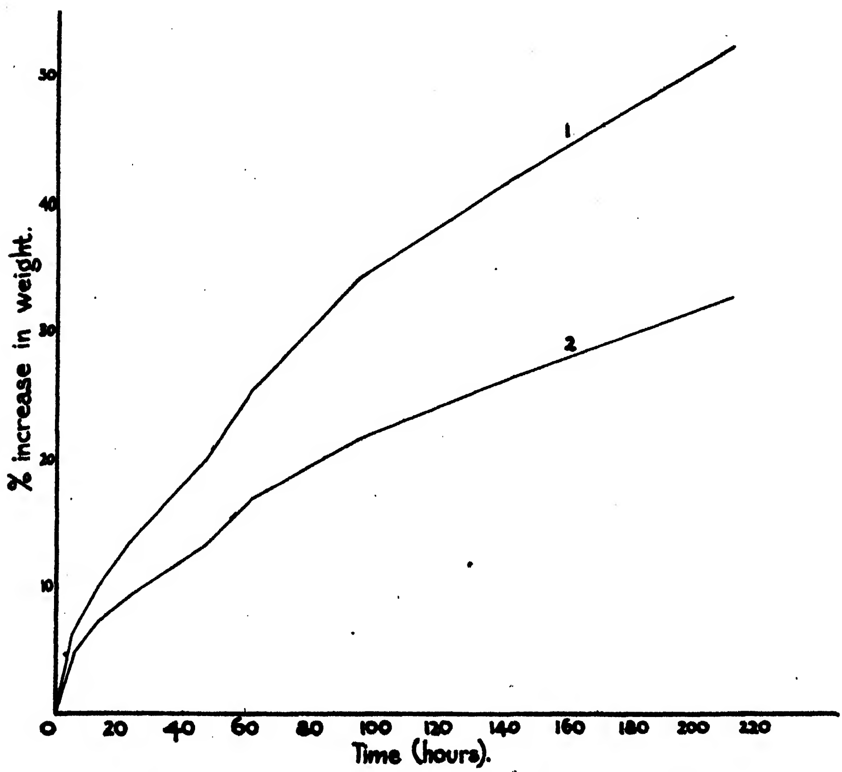


FIG. 13.—Fat-absorption curves for tubes: (1) normal rubber; (2) make B, containing reclaim.

TUBING

With the danger of an acute rubber shortage arising, work was done on the behaviour of rubber tubing containing a fair percentage of reclaim. In the tubing used in the following tests the normal raw-rubber content of the vulcanizate (50 per cent. to 60 per cent., depending on make) was reduced by one-third, this being made up by whole-tire reclaim. Tubing so constituted has a fairly rough surface and therefore presents slightly more difficulty in cleaning. However, in an emergency this would not be serious if the other properties justified its use.

Experiment 1

The following series of tests were carried out on claw tubes (together with milk and air tubes in the field tests) supplied by firm B.

Bending Tests.—These were carried out as previously described, with the following result :—

	No.	Life (Hours).
Standard	1	36·8
	2	25·2
Reclaim	1	17·7
	2	19·8

$X = 12{\cdot}4$; $S = 7{\cdot}2$.

The differences are not significant (P = 5 per cent.).

Fat Absorption.—The fat-absorption curves for the rubbers under discussion, determined on ½ in. lengths, are set out in the accompanying figure (Fig. 13). The sample containing reclaim shows distinctly better fat resisting properties than the normal sample.

Other Physical Properties :—

	Shore Hardness.	Shore Elasticity.
Standard	44	98
Reclaim	60	78

The lower " elasticity " figure indicates the likelihood that reclaim-containing stocks will show undesirable properties due to " permanent set."

Field Life.—Under normal farm conditions reclaim claw tubes gave a life varying from 66 to 266 days. These tubes ended up by breaking through at the ends where they are bent in use. The controls of normal rubber put up a poor performance, giving only 46 days' use before breaking through at the end.

Experiment 2

The following tests were carried out on make A tubing containing whole-tire reclaim in one case and reclaim from rubbers filled with clay, &c., in the other. These are described as " black " and " red " respectively and, as in the previous case, contain reclaim to the extent of one-third the normal raw rubber content.

Bending Tests :—

Type.	Life (Hours).
Standard D	53·1
Standard A	43·2
Standard D	54·3
Standard A	37·6
Reclaim A (red)..	77·9
Reclaim A (black)	71·0
Reclaim A (red)..	37·1
Reclaim A (black)	12·0

Making a comparison between the above groups gives the " t " ratio $\bar{d}/S\bar{d} = 0{\cdot}21$, which is well below significance. The variance of the two groups is an important figure ; for the controls it is 64·4, for the reclaim tubes 521·1. The high figure for the reclaim tubes indicates the possible unreliability of the latter in use.

Fat Absorption.—This is set out in the accompanying figure (Fig. 14).

Field Tests.—The black reclaim claw tubes gave an average life of 275 days, which is excellent. The red tubes became flabby and, while giving a fair performance, were somewhat inconvenient to use. They were, however, practically usable for 150 to 200 days. The controls in these experiments had lives of 166 days (make B) and 86 days (make A).

The reclaim claw tubes have generally given a good performance and, apart from their roughness, are apparently as good as or better than the usual rubber.

It should be noted that all tubes used in these experiments are of standard dimensions (N.Z.S.S. E.74).

Milk and air tubes have also been put into use made of the partly reclaim rubbers described above. These have so far lasted for two seasons satisfactorily and are apparently not markedly inferior to the controls.

It may be concluded that whole-tire reclaim can be used to replace one-third of the raw rubber in milking-machine tubing.

Experiment 3: The Use of Carbon-black Stocks for Claw Tubing

Three types of carbon-black claw tube have been tried. Their bending lives and other properties are set out below. In all cases the controls for the bending tests are of the same make. All tubes are of standard dimensions (N.Z.S.S. E.74).

Make D:—

	No.	Life. (Hours).
Controls	1	53·3
	2	46·2
	3	77·4
	4	60·3
Carbon black	1	199·4
	2	greater than 287·3 (1,000,000 bends).
	3	„
	4	162·4

The mean difference (taking the maximum life at 287·3) = 174·8.

Standard deviation = 62·5. The difference between the groups is highly significant (P = 1 per cent.).

Make B: Bending Test and Fat Absorption:—

—	No.	Life (Hours).	Fat Absorption (45°) after Twenty-four Hours (per Cent.).	Shore Hardness.	Shore Elasticity.
Control ..	1	25·5	13·68	51	93
	2	4·8	13·47		
Carbon black	1	Greater than 287·3	23·66	32	90
	2	„	22·00		

The carbon-black stocks in this case, though excellent for bend resistance, have too high a fat absorption and too low a hardness number to be satisfactory in practice.

Make A: Bending Test, Fat Absorption, &c.:—

—	No.	Life (Hours).	Fat Absorption (45°) after Twenty-four Hours (per Cent.)	Shore Hardness.	Shore Elasticity.
Control ..	1	54·9	8·99	57	73
	2	66·9	8·97		
Carbon black ..	1	351·4	11·82	57	87
	2	350·6	11·60		

These carbon-black tubes have good fat-resisting properties, though not as good as the controls, which are excellent. The hardness and elasticity are similar to the controls, while the bending resistance is outstanding. Both samples bent well over one million times before breaking down.

Field Tests.—The field-test results for the carbon-black claw tubes are not complete at the time of writing owing to the extraordinarily long life of one of the sets of tubes. Make A carbon-black claw tubes have been in use for one year on two farms and the rubber shows no surface cracks. It has developed a shiny surfacy which cleans well. In fact, this type of claw tube is much better than any other type tested in all respects. Make D

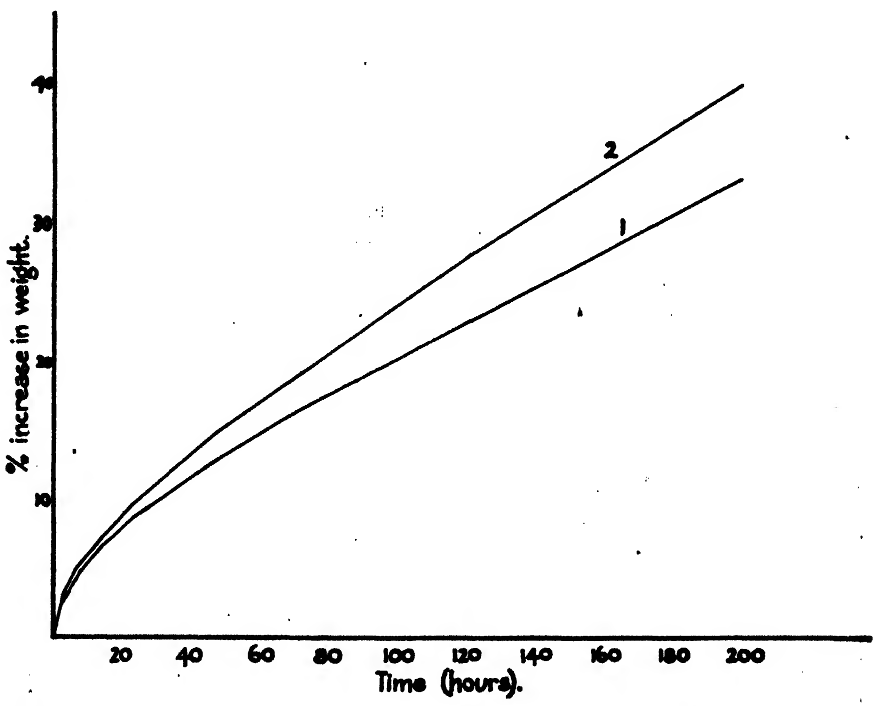


FIG. 14.—Fat-absorption curves for—(1) make A black reclaim—containing rubber; (2) make A red reclaim—containing rubber.

carbon-black tubes have given a field performance which is better than the controls. In fact, the samples, while badly cracked, are still in use at the time of writing after a season's use. Make B carbon-black tubes after use for some three months showed signs of cracking. Their performance is therefore not as satisfactory as good normal rubber.

The results indicate that where the hardness of a carbon-black stock is increased sufficiently to give it good fat resistance, its excellent bend-resisting properties make it an ideal rubber for claw tubing. Its well-known ability to resist cuts and knocks is also valuable, and the development of the shiny surface is very important from the point of view of cleanliness.

SOME MISCELLANEOUS TESTS

A Test for the Collapsibility of Rubber Tubing

The instrument consists of two $\frac{9}{16}$ in. tubes fixed to a base so that the ends are 6 in. apart, and one is pivoted so that it moves about an arc whose centre is midway between the ends. One tube is blocked, while the other is connected to a source of vacuum. The movement of one tube with respect to the other is measured in degrees on a circular scale and the result expressed in the angle through which the tube is bent before it kinks. In most cases the kinking occurs quite suddenly.

The following results illustrate the variation of this property. The tests were done at a 25 in. vacuum :—

Type.	No.	Collapse Angle (Degrees).	
		Clockwise.	Anti-clockwise.
Claw tube	1*	76	76
	2*	64	55
	3*	70	70
	4	92	95
		Average.	
Air-tube	1	72	
	2*	59	
Milk-tube	1	58	
	2*	40	

Those marked with an asterisk would be regarded as unsatisfactory. Where there is a marked difference between the two readings, the wall thickness is not uniform.

The test, though empirical, is quite useful.

Geer-oven Tests

The following are the results of a ten-day ageing test in the Geer oven at 71° C. Ring samples, $\frac{7}{8}$ in. by $\frac{1}{8}$ in. by $\frac{3}{32}$ in., were used. The actual cross-sections were measured in this case with a Vernier microscope and the results calculated as pounds per square inch of original cross-section :—

Make.	Original Strength (lb./sq. in.).	Final Strength.	Percentage Change.
A	2,796	2,786	0·4
B	2,110	913	56·7
C	2,152	1,501	30·2
C + reclaim	2,376	2,044	14·0
D	2,220	1,832	17·5
D (carbon black)	2,801	2,345	16·3
D (smooth)	2,030	1,727	14·9

The outstanding performance of make A in this test is the most noteworthy feature of the table. Makes B and C do not give satisfactory results.

Analyses of Typical New Zealand Milking Rubberware

The writer is indebted to the Dominion Analyst for the following analyses :—

No.	Make.	
1 ..	B.	⅞ in. standard straight inflation.
2 ..	A.	,,
3 ..	C.	,,
4 ..	D.	,,
5 ..	D.	Standard claw tube.
6 ..	A.	,,

The samples were examined in accordance with B.S. Specification No. 903–1940, " B.S. Methods of Testing Vulcanized Rubber " :—

——	1.	2.	3.	4.	5.	6.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Acetone extract	3·9	5·3	3·8	3·7	3·3	3·8
Chloroform extract ..	0·3	0·1	0·5	0·3	0·5	0·1
Alcoholic potash extract ..	0·3	0·5	0·5	0·4	0·3	0·4
Sulphur in acetone ..	1·19	0·69	0·68	0·27	0·12	0·19
Rubber-combined sulphur ..	2·89	2·60	2·68	2·37	1·51	1·61
Total fillers	27·0	25·5	20·3	27·9	41·0	39·6
Ash	22·3	20·7	14·3	27·4	34·1	40·4
Zinc oxide	..	2·5	..	3·1	3·3	3·0
Antimony sulphide (as Sb_2S_5)	8·0	..	9·8	..	..	..
Sulphur in total fillers ..	2·08	..	3·26	..	..	..
Rubber content	67·6	68·0	74·4	67·3	55·0	56·1

N.B.—The rubber content is calculated as follows : Rubber content = (100—(acetone extract + chloroform extract + alcoholic potash extract + total fillers + rubber-combined sulphur)) × 1·03.

Dr. C. O. Hutton examined samples of the fillers, and reported as follows —

No. 1.—Calcium carbonate, quartz, and plagioclase. Maximum grain-size, 0·1 mm., but the average is considerably less.

No. 2.—Quartz, feldspar, muscovite, rare glass. Average grain-size, approximately 0·03 mm. ; grains up to 0·1 mm. were noted. The bulk of the residue is composed of rounded, brown, poorly birefringent material ; the refractive index is about 1·58. It is not possible to identify this material for certain owing to heavy pigmentation. However, although the R.I. is somewhat high, it is suggested that it is kaolin.

No. 3.—Quartz, feldspar, and muscovite ; possibly clay. Average grain-size, 0·03 mm.

No. 4.—Quartz, feldspar, muscovite, tourmaline, clinozoisite, glass. As in No. 2, the bulk of the residue is composed of the brown material, tentatively referred to as kaolinite. Average grain size, 0·02 mm. ; rare grains up to 0·1 mm.

No. 5.—Mainly the brown material, kaolinite (?). Remainder as in No. 4.

No. 6.—Almost entirely $CaCO_3$. Average grain-size, 0·005 mm. A minor amount of quartz in grains to 0·1 mm. This material has the appearance of Oxford chalk.

An Experiment with Composite Tubing

Samples of milk and air tubing were made up with a thin (approximately $\frac{1}{16}$ in.) inner layer of normal rubber surrounded by a normal thickness of whole-tire reclaim. The milk-tube, which is subjected to washing with boiling water and caustic soda, developed trouble due to the inner layer separating from the reclaim. The air-tube has been in use for one season and is still functioning. Provided that a more satisfactory bonding could be effected—*e.g.*, by the use of an intermediate type of rubber—this type of tube could well be used in an emergency, as it consumes very little raw rubber.

ACKNOWLEDGMENTS

The writer is greatly indebted to Messrs. Barnet Glass Perdriau Rubber Co., Ltd., Messrs. Empire Rubber Mills, Ltd., and Reid (N.Z.) Rubber Mills, Ltd., for their co-operation and help in the above work. The assistance of the Dominion Analyst (Mr. R. L. Andrew) and Mr. J. L. Mandeno, of Dominion Laboratory, and Mr. K. G. McNaught, of the Chemistry Laboratory, Department of Agriculture, has also been invaluable throughout the experiments recorded above. Mr. Sawtell, of this laboratory, has carried out many of the physical tests involved and has constructed most of the apparatus. The writer is also grateful to those who helped in the field tests: Professor W. Riddet, who permitted the use of the cow-sheds at Massey Agricultural College for much of the field testing-work; Messrs. J. D. Sargent and J. Robertson, who supervised the tests at Massey College; and Messrs. F. and J. Whiteman, on whose farms many trials were carried out.

INDEX

VOLUME 26, SECTION A

Date of Issue	Date of Issue	Date of Issue
5.2.57		

GIPNLK—H-40 I.A.R.I.—29-4-55—15,000